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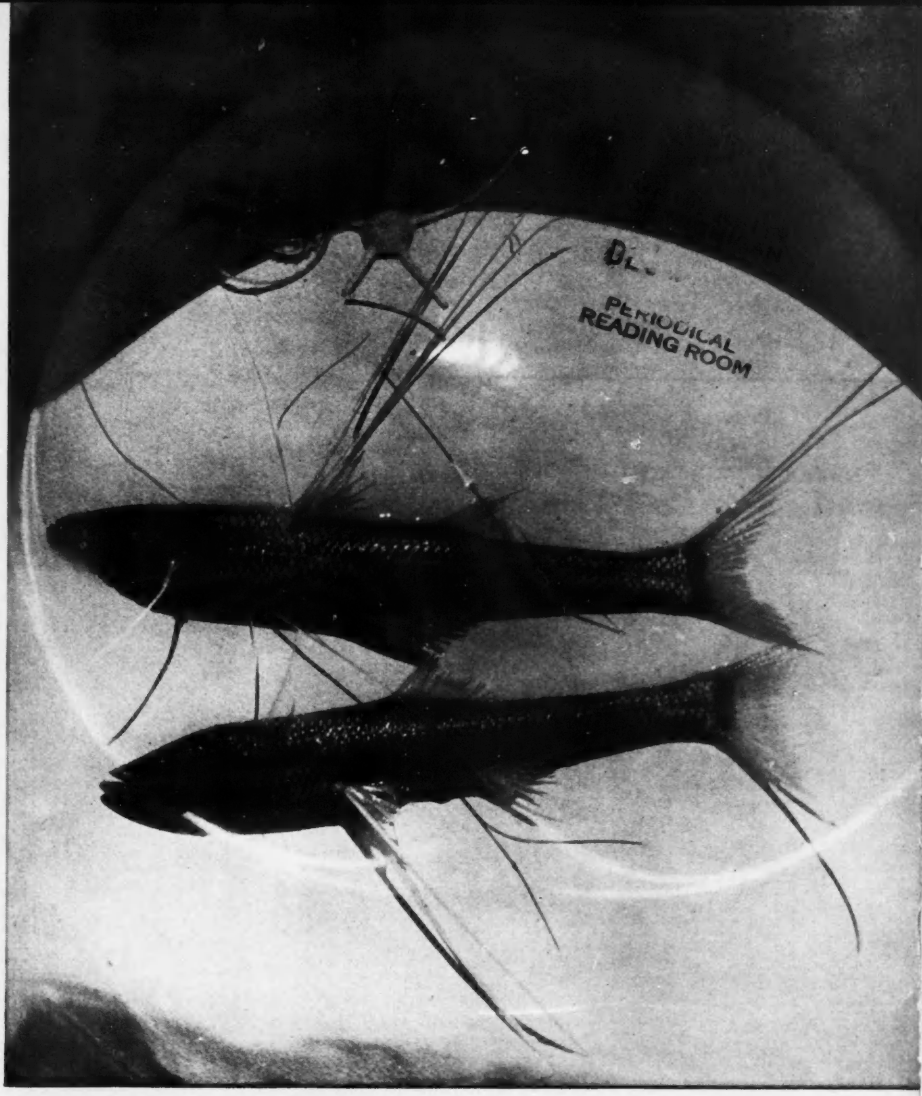


A Deep-Sea Fish brought up from 2700 fathoms. (See "The Life of Deep-Sea Fishes".)

DECEMBER 1954 2/-

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THE MAGAZINE OF SCIENTIFIC PROGRESS

*Editor* WILLIAM E. DICK, *B.Sc, F.L.S.* *Editorial Office* 244 High Holborn, WC1 Chancery 6518
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## THE PROGRESS OF SCIENCE

### DOING SOMETHING ABOUT THE WEATHER

After this year's summer, one of the wettest in living memory, the announcement that the Meteorological Office is to carry out "trials of methods of weather modification"—the term weather-modification usually means rain-making experiments—has evoked no cheers. Beachcomber, we were happy to see, did not miss this opportunity for a joke, and he conjured up a picture of Dr. Strabismus (Whom God Preserve) of Utrecht merrily using iodised icebergs and balloons with gigantic salt-cellars attached to set up what Beachcomber mockingly called "defragination"!

"Weather modification" (which cannot hope to compete with defragination as a technical term!) can, however, mean other things beside rain-making. The U.S. Air Force, for example, supported such experiments because they might show the way to clear the fog and cloud that render airfields unusable. In any event, we see no reason why scientists need feel apologetic about such experimentation; there is justification enough in the fact that the public is always grumbling because scientists don't do anything about the weather. The British experiments, which will begin in the spring or summer of 1955, represent an attempt to do something.

A treatment of the subject of weather-modification more enlightening if less amusing than Beachcomber's was given recently in a lecture to the Royal Society of Arts. The lecturer was Dr. Irving Krick of the American Institute of Aerological Research, a private organisation which has carried out a great many rain-making experiments. He took the story back to the earliest attempts to induce rain clouds to give up their charge of moisture. As early as the 1890's patents were taken out in both the U.S.A. and Europe on devices for projecting dry ice into the clouds. Their idea was to shoot projectiles loaded with liquid carbon dioxide under great pressure into likely-looking clouds, so that, when the projectiles burst, the sudden expansion and resultant cooling of this material would produce dry ice which would chill the air and result in the formation of ice crystals. These would grow at the expense of surrounding droplets, finally becoming snowflakes large enough to fall out. The early attempts to precipitate rain failed because the knowledge was not available to enable them to decide when and where to apply the dry ice, and in what quantities. In the 1930's a Dutchman, Veraart, tried seeding super-cooled clouds with dry-ice pellets, and he came to the conclusion that the result was increased rainfall in the vicinity of his operations. But the Dutch Government was not interested in his appeal for financial support for further experiments and his trials came to an inconclusive end.

The whole subject was vigorously revived by experiments made by Irving Langmuir, Vincent Schaefer and Bernard Vonnegut of the Schenectady research laboratories of the General Electric Company of America. Their first experiments were done in the laboratory using a refrigerated box with a lid. When the temperature of the box was at about $-5°F$, the experimenter had only to breathe into the cabinet to create a fog of super-cooled droplets. Then when he introduced a fragment of dry ice into the super-cooled system, a cloud of tiny snowflakes was produced which rapidly settled. This type of experiment was repeated with the box at different temperatures with other 'seeding' substances besides dry ice.

The G.E.C. group also tried large-scale experiments out of doors. In his recent book *Explorations in Science*, Waldemar Kaempffert describes one of the first of these in which six pounds of dry ice grains were scattered on a promising-looking cloud from an aeroplane. The result was that streamers of snow started to pour out from the bottom of the cloud and pillars of cumulus cloud rose from its top. Schaefer, who was in the plane, saw a brilliant halo round the sun—the kind of halo caused by ice crystals that is often seen at night round the moon.

Dr. Krick and his colleagues followed up the early work of the G.E.C. group with a series of large-scale rain-making experiments. The G.E.C. scientists had discovered that a number of substances other than dry ice could be used for

this purpose, and silver iodide proved to be one of the most effective. It readily volatilises, and advantage of this fact was taken to develop smoke generators which could be used on the ground to send up a stream of silver iodide crystals. There was then no longer any need to 'seed' clouds from the air; the smoke generators on the ground did just as good a job. This technique has been tried in several countries including South Africa and Australia, and presumably Britain's Meteorological Office will use it in its 1955 experiments.

The point of seeding clouds with crystals of a substance such as silver iodide is this: a cloud below 32 F does not necessarily precipitate either snow or liquid water drops; ordinarily dust particles or some ice crystals must be present to serve as nuclei for water vapour to condense on and start any substantial precipitation. In artificial rain-making the silver iodide crystals take the place of the nuclei which do the trick in nature. (These remarks apply to the condensation of water involving ice formation; in rain formation there can be condensation of water vapour direct to liquid water without any ice being involved. The latter quite separate mechanism is not affected by substances such as silver iodide; in rain-making experiments which attempt to exploit this mechanism, salt crystals or small amounts of liquid water have been used for 'seeding' clouds.)

Dr. Krick showed how the technique would work on a cloud of the type depicted in Fig. 1. The vertical scale indicates altitude in feet. The different temperature levels in the atmosphere are indicated; they are typical of an average summer day in the U.S.A. The cloud formation is meant to be a typical local storm cloud. The triangular form drawn inside the cloud illustrates the decrease of moisture with altitude in the atmosphere. At lower levels there is more water available for condensation and precipitation than at higher levels in the atmosphere because, at the cold temperatures characteristic of high altitudes, air will not hold as much water vapour in suspension as it will at the warmer temperatures found at lower altitudes.

In the cloud mass depicted in Fig. 1, there are three zones designated in the regions where temperatures are colder than freezing. In the lower zone, in a temperature range between 32 F and 25 F, the cloud is unaffected by artificial nucleation because silver iodide crystals do not act as ice nuclei until temperatures are colder than 25 F. In the zone between 25 F and 5 F the water content can be affected by silver iodide nucleation. Thus, this is the zone within the cloud mass in which silver iodide will form ice crystals. On the other hand, natural nucleating materials do not begin to take effect until the temperatures are colder than 5 F and, therefore, are ineffectual within this layer of cloud. At temperatures colder than 5 F, water vapour in the cloud can be affected by substances occurring in nature which produce ice crystals. In the case of most natural nuclei, this effect is not complete, however, until temperatures are near −13 F, so there is still, in this segment of the cloud, an action of silver iodide in augmenting nature's ice crystal production. Finally, at levels of approximately −40 F, clouds crystallise without nucleation of any kind because this is the temperature level at which ice crystals seem to form spontaneously in saturated air, says Dr. Krick.

The distribution of water vapour in the atmosphere is such that the segment of cloud affected by artificial nucleation contains much more water than the higher portions of the cloud influenced by natural nucleation. Consequently in some instances, the amount of water that is precipitated to the earth by the artificial nucleation process may exceed that which is precipitated through the effects of natural nucleating materials in the atmosphere. In general, the ratio of induced precipitation to natural precipitation is greater in winter than in summer because the greater proportion of cloud mass lies at the temperature zone influenced by cloud seeding. This ratio is greater in higher latitudes than in lower latitudes for the same reason.

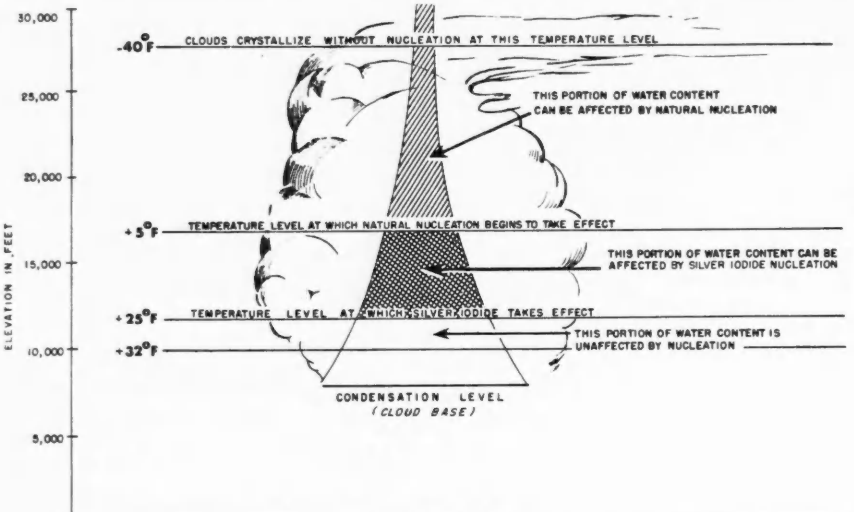



FIG. 1. The different temperature levels in a cloud: note that the response to 'seeding' with silver iodide varies in the different cloud regions.

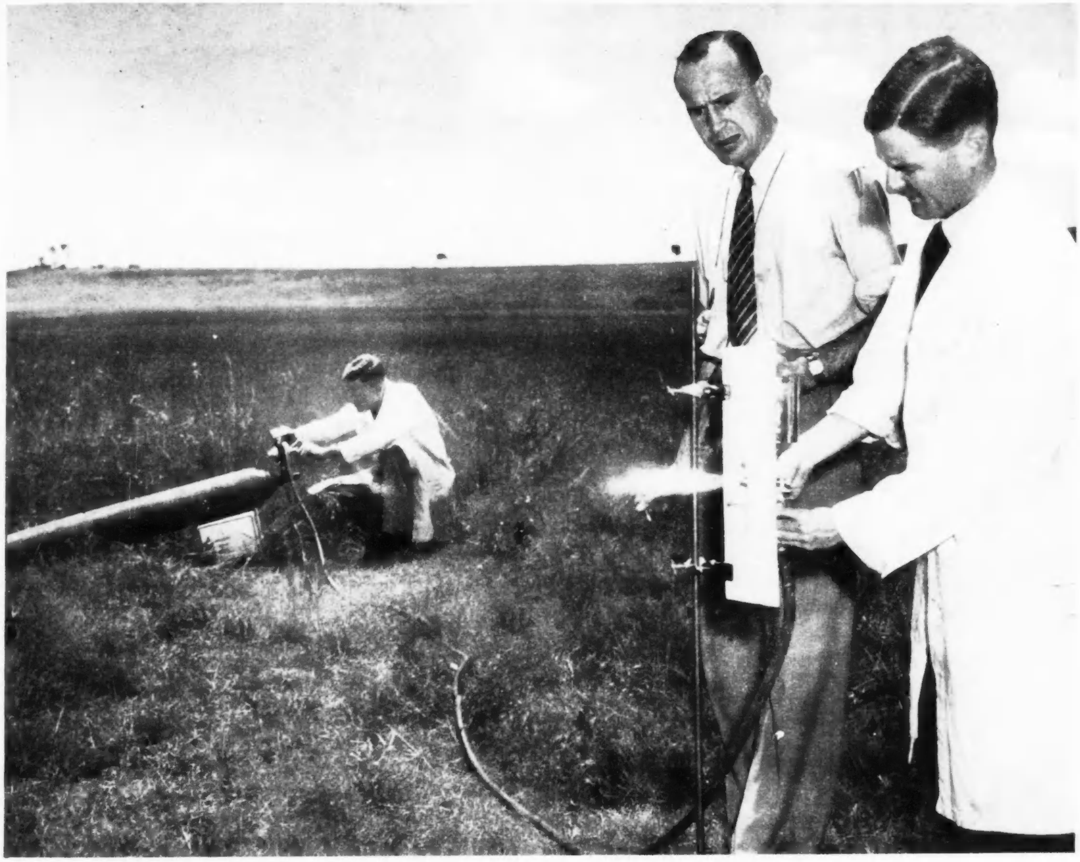


FIG. 2. South African scientists are among those who have been investigating rain-making techniques. Here two of them are seen watching a small experimental generator which is producing silver iodide smoke. (*Photo: Johannesburg Star*)

Dr. Krick states that the effects of silver iodide cloud seeding can readily be recognised because of the transformation that takes place in a treated cloud. Before nucleation, the cloud is composed chiefly of super-cooled water drops. Following the seeding operation, a portion of the cloud above freezing levels is transformed into ice crystals. Ice crystal clouds have a wispy, fibrous appearance, whereas clouds composed of water drops, even at temperatures below freezing, have hard, well-defined outlines. These differences cannot be observed from the ground during a general storm when the sky is completely overcast and the ice crystal clouds lie embedded in the cloud cover. It is relatively simple to discern these differences during summer thunderstorm situations when the cloud forms are isolated.

Although such isolated cloud formations frequently are susceptible to cloud-seeding operations, in general the most important successes are attained from storm systems in which cloud sheets form a solid mass covering thousands of square miles.

In cloud-seeding work the silver iodide (a yellowish powder at ordinary temperatures) is usually vaporised by subjecting it to a high temperature. Dr. Krick says that the optimum temperature is approximately 2500 F. Various methods are in use, ranging from an acetone solution of silver iodide that is passed through a hydrogen or butane flame which burns at approximately 1800 F, to the burning of sized foundry coke impregnated with a solution of silver iodide in acetone in a furnace in which the optimum temperature of 2500 F is easily attained. He himself favours the latter method.

The aim is to produce as many silver iodide crystals capable of acting as nuclei as possible; the number of such crystals produced reaches astronomical figures—Dr. Krick reckoned that for every gram of silver iodide put into a smoke generator one ought to get $10^{14}$–$10^{16}$ nuclei!

For readers who are interested in more details, we would recommend them to get hold of Dr. Krick's full paper which has been published in the *Journal of the Royal Society of Arts* (1954, Vol. 102, No. 4924, pp. 447–65). This also contains a useful set of references on this subject.

## THE SCIENTIST'S PAY PACKET

There are quite a large number of scientists who earn high salaries, but the commonly held idea that scientists generally must receive big salaries now that Britain spends so much on research and development is a long way off the mark. Gross expenditures on scientific work are no guide as to what the size of the boffins' pay packets is. For the period 1954–5 the estimated expenditure on Ministry of Supply research and development is £163,700,000, but a very high proportion of that money goes on things other than salaries. That proportion is less in, say, the case of the DSIR's £8,200,000, but still salaries represent a relatively small part of the total.

Recently the scientific correspondent of *The Financial Times* made a useful attempt to give a general picture of the kind of salaries scientists receive. The tabulated figures he cited for different kinds of scientists in industry and universities, and for science teachers, are quite revealing and are well worth publishing again. A word of explanation is necessary in this connexion: with the exception of the figures for the academic scientist, which were obtained from a sample containing a rather high proportion of University Readers and Professors, the salaries given are average salaries over a field where the quality of the worker and the size of his reward can vary considerably. According to this *Financial Times* article, it is fair to say that the average scientist with a first-class degree and lengthy research experience can expect a salary of £1500–£1700 at 50; a salary that is unlikely to be greatly increased, if at all, before his final retirement. The article makes the comment that "this does not compare favourably either with the average net earnings of £2200 a year by general medical practitioners or with the rewards of the business executive. Yet the responsibilities of the research scientist working on industrial projects or on defence projects may be just as heavy as those of the business executive or the doctor, and are often greater. His training is expensive and often long."

In the scientific civil service there are a few exceptionally highly paid posts with salaries between £3000 and £5000, but these can almost be counted on the fingers of two hands. There are scientists in industry in this salary range, but again they are very few in numbers.

### AVERAGE ANNUAL SALARIES OF SCIENTISTS

| Age group | 26–30 | 31–35 | 36–40 | 41–45 | 46–50 |
|---|---|---|---|---|---|
| | £ | £ | £ | £ | £ |
| Industrial Chemist (*a*) | 812 | 1025 | 1237 | 1400 | 1600 |
| Industrial Biologist (*b*) | 748 | 991 | 1417 | 1814 | 1835 |
| Industrial Physicist (*c*) | 800 | 1035 | 1175 | — | — |
| University Scientist (*b*) (Biologist) | 667 | 889 | 1352 | 1589 | 1789 |
| School Teacher (*d*) | 775 | 850 | 925 | 990 | 1010 |
| Civil Service (*b*) and Government-aided Institutions | 612 | 850 | 1061 | 1366 | 1405 |

(*a*) Based on R. Institute of Chemistry inquiry, 1953. (*b*) Based on Institute of Biology Survey, 1953. (*c*) Based on Institute of Physics Survey, 1953. (*d*) Based on Burnham Committee Report on Teachers' Salaries, 1954. (*e*) A small back-dated increase on these figures for Civil Service scientists has just been granted.

The article draws attention to a new phenomenon, "the businessman-scientist", has come into existence, and is increasing in numbers. He is trained in both science and business, and with few exceptions seems always to command a higher wage than the research scientist, however brilliant.

The table brings home very forcefully the counter-attractions to a career as a science master. It now seems to be generally realised that salaries in science teaching will have to be increased if the supply of new recruits to the scientific profession is to be maintained. But still the Government does nothing about this vital matter. The Federation of British Industries has produced a useful report on the shortage of science teachers; industrialists could put considerable pressure on the Government and get some action on this issue which is of vital importance to industry itself and also to the nation as a whole.

## TRIDAC AND AGWAC

The construction and installation of two large electronic analogue computers has recently been completed by a British firm.

TRIDAC which is the larger of the two machines, is installed at the Royal Aircraft Establishment, Farnborough. This computer has 8000 valves and occupies 6000 feet of floor space.

AGWAC, which is installed at the Long Range Weapons Establishment, Salisbury, Australia, has around 1900 valves in its circuitry.

Both machines will be used for development research on guided missiles and high-speed aircraft. By simulating the flight of the missiles and planes electronically, they save wastage and expenditure on experimental missiles and aircraft, and yet enable their performance under different conditions in actual flight to be accurately recorded and assessed.

TRIDAC is a convenient abbreviation for the full title of the Farnborough computer, which is the Three-dimensional Analogue Computer. This machine can simulate the flight of both an enemy bomber and that of the intercepting machine (either a guided missile or a plane) simultaneously in three dimensions, and continuously records the relative positions of the two machines during their flights. The progress of the interception is recorded on the dials of meters, on moving diagrams on screens, and more permanently by pens moving over charts. In this way a complete record of the flight of the missiles or aircraft under test can be obtained from start to finish. The realism of the simulated flight to the onlooker is enhanced by the fact that one of the moving diagrams records the whole sequence of events in 3-D.

Alterations in the speed and height of the combatants, and all their various twists and turns, are simulated and recorded. The speed at which the simulated flights take place is exactly the same as would be the case if they were really occurring and actual planes and missiles were being used. TRIDAC is said to be accurate to within about 0·1%. Work on the building of TRIDAC was a big job and took many months; work on it started in 1950, and it cost £750,000.

Both TRIDAC and AGWAC consume considerable

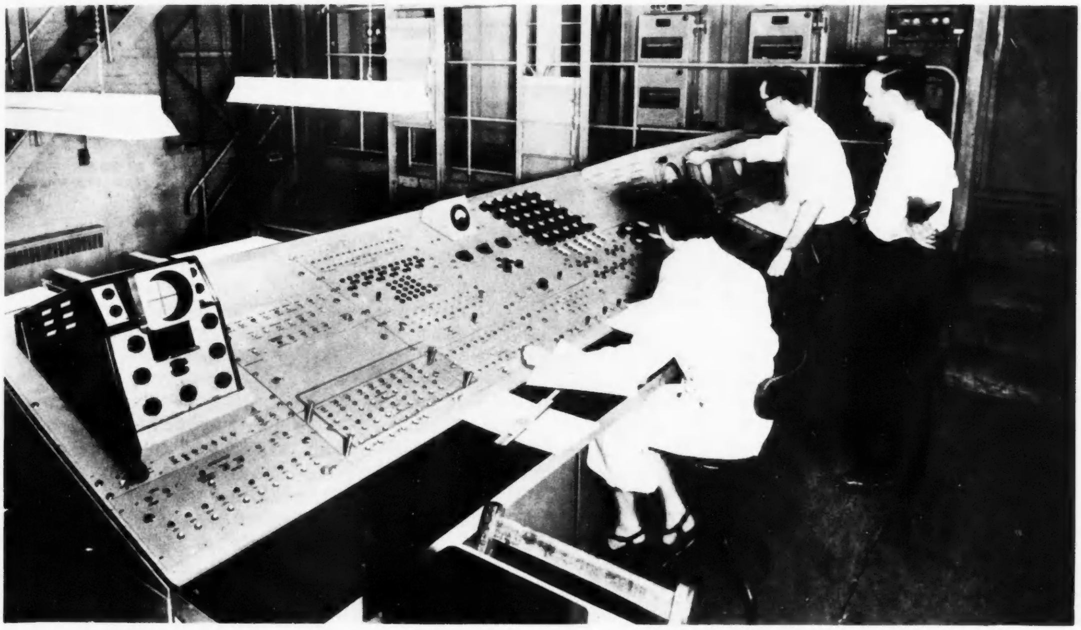


FIG. 3. The control panel of TRIDAC at the Royal Aircraft Establishment. This giant calculating machine which occupies 6000 square feet of floor space was built by Elliott Brothers of London.

quantities of electricity; TRIDAC, for example, uses enough electricity to light a small town. Both computers generate considerable quantities of waste heat when they are operating; even in the smaller of the two computers, the total amount of power dissipated in this way is around 25 kilowatts. This waste heat must be removed; changes in temperature of more than 8°F in either direction from the satisfactory operating temperature of 76°F will alter the electrical behaviour of certain elements in the circuits, thus affecting the accuracy of the machine. Heating may also be necessary under some conditions in order to maintain the temperature close to 76°F, and the thermostatically-controlled cooling circuit of the computing equipment of AGWAC contains both a cooler battery and an electric heater.

TRIDAC is the biggest electronic computer yet built in Britain, and must rank as one of the largest analogue computers in the world.

## THE AUTOMATIC FACTORY

Prompted by *The Times* correspondence on "AUTOMATION" which was aroused by a report of Sir Ben Lockspeiser's speech to the Institute of Directors' annual conference, several readers asked us to print the passage in his talk dealing with automatic factories. We were also asked whether any books on this subject have been published.

The only book we can trace which is devoted exclusively to the subject is John Diebold's *Automation: The Advent of the Automatic Factory*. This American work was published in 1953 and is distributed in Britain by Macmillan's.

We have been able to borrow a copy of Sir Ben's speech, and we print the relevant passage below:

*Technological progress in these days can be very rapid and the full exploitation of electronic advances is likely to introduce a revolution in business offices and production shops second only in importance to the Industrial Revolution itself. The Russians claim to have designed and to be operating a fully automatic factory of this type for making pistons, with a production capacity of 3500 piston heads in twenty-four hours, for supplying the whole of the Soviet light car industry. The successive processes involve casting, heat treatment, hardness, testing, machining, boring, grinding, grooving, polishing, inspection, sorting, greasing and packaging, all of which are accomplished in turn automatically. The total number of men required in each shift is said to be nine, the cost of production halved, with greater precision in manufacture (as would be expected) than is attainable under manual control. There is nothing here that would not be anticipated from the full application of electronic control to production engineering. An American plant that is almost fully automatic is the Rockford Ordnance plant, which manufactures 155 mm. steel shell casings. The processes include several forging operations, heat treatment, descaling, boring, turning, drilling, screwing and annealing.*

Our readers are likely to be interested in the announcement of the conference which the Institution of Production Engineers plans to hold in June 1955 to discuss the technological and other problems inherent in the advent of the automatic factory. (The Institution's address for those who want it is 85 Fountain House, Park Lane, W.1.)

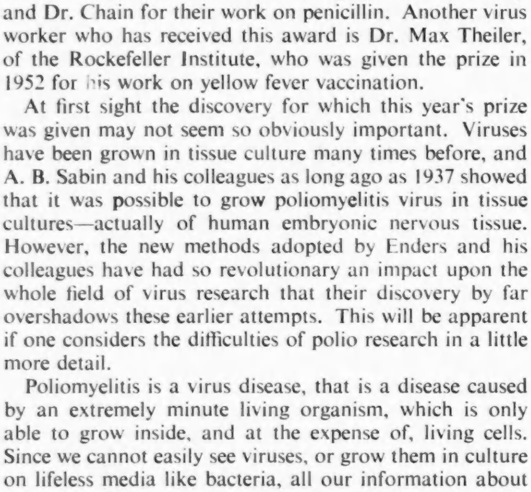
# A NOBEL PRIZE FOR POLIO RESEARCH

## DR. F. K. SANDERS

The 1954 Nobel Prize for Medicine and Physiology has been awarded to three American scientists—Professor John F. Enders of Boston, and his two associates, Professors Frederick Robbins and Thomas Weller. The award was given for their discovery of a method of growing poliomyelitis virus—the germ of infantile paralysis—in *tissue culture*—that is to say, in portions of animal tissue kept alive artificially outside the body. This category of Nobel Prize is often given for some major advance in man's fight against disease; it was awarded, for instance, to Sir Alexander Fleming, Sir Howard Florey and Dr. Chain for their work on penicillin. Another virus worker who has received this award is Dr. Max Theiler, of the Rockefeller Institute, who was given the prize in 1952 for his work on yellow fever vaccination.

At first sight the discovery for which this year's prize was given may not seem so obviously important. Viruses have been grown in tissue culture many times before, and A. B. Sabin and his colleagues as long ago as 1937 showed that it was possible to grow poliomyelitis virus in tissue cultures—actually of human embryonic nervous tissue. However, the new methods adopted by Enders and his colleagues have had so revolutionary an impact upon the whole field of virus research that their discovery by far overshadows these earlier attempts. This will be apparent if one considers the difficulties of polio research in a little more detail.

Poliomyelitis is a virus disease, that is a disease caused by an extremely minute living organism, which is only able to grow inside, and at the expense of, living cells. Since we cannot easily see viruses, or grow them in culture on lifeless media like bacteria, all our information about them has to be obtained indirectly. Until recently this had to be done by injecting material thought to contain virus into susceptible animals, or else into developing hen's




This diagram shows the sequence of operations in the cultivation of poliomyelitis virus in tissue cultures.

eggs, and then watching for the typical signs of the disease in question. If large numbers of eggs or animals are used, we can not only detect the presence of a virus, but also measure crudely how much of it is present. For many years eggs and small animals like mice have been the mainstay of virus research, and quite a lot has been learned about those viruses which can be persuaded to grow in one or the other of these hosts. Unfortunately polio virus will not grow in eggs, and the only animals besides man which are regularly susceptible to polio viruses of all three immunological types are monkeys and chimpanzees. These animals are expensive and hard to look after, and thousands would be needed for an adequate attack on the polio problem. Even if we had the financial resources and the buildings to house them, it is doubtful if enough monkeys could be caught to satisfy a world demand. As long as polio research remains dependent on monkeys and chimpanzees, our knowledge of this virus is bound to lag behind that of less fastidious viruses which will grow in eggs or mice.

The first importance of the discovery of Enders and his colleagues concerns this side of polio research. They have found a cheap and reliable substitute for the monkey, which can be used both to grow the virus, and to detect its presence. This advance depends on the use of the roller tube method of tissue culture developed by Gey and Gey at the Johns Hopkins Hospital in the late 1930's and used by them in cancer research. The method differs from the conventional types of tissue cultures previously used in virus work in that the tissues can be kept alive for relatively long periods without sub-culturing, while the amount and composition of the culture medium can be more accurately controlled. In the kind of cultures favoured by the polio workers, pieces of tissue (both monkey and human tissues have been used) are removed from the body and cut up into a large number of very small pieces, each about 1 mm. cube in size. A few of these tiny fragments are then stuck to the wall of a glass tube by means of a clot of blood plasma, and the tube partly filled with a suitable nutrient fluid. This normally consists of a mixture of blood serum and a saline solution containing the inorganic salts of blood in appropriate concentration, together with a little chick-embryo extract to promote tissue growth.

The tube is then tightly corked, and is placed lying on its side in a slowly revolving drum, which is kept at body temperature (*see diagram*). As the drum turns, the tissue fragments, and the plasma clot in which they are embedded, are alternately bathed in nutrients and exposed to the warm, damp atmosphere of the tube. Under these conditions, cells begin to grow out of the piece of tissue after a few days and penetrate into the clot of plasma; after about a week each tiny piece of tissue is surrounded by a feathery halo of independently living cells, which can be clearly seen when a microscope is trained on the wall of the tube. Some of the cells which grow out

The three Nobel prizewinners; from left to right, they are Dr. Thomas H. Weller, Dr. John Franklin Enders and Dr. Frederick C. Robbins. They did their original polio work together, working at the Children's Medical Centre of Harvard Medical School, Boston. Dr. Robbins has since moved to Cleveland Hospital.

in this way have a remarkable beauty, and many film records have been made of their activity. If now material containing poliomyelitis virus is added to a tube containing such outgrowths of cells, the virus multiplies within the cells, and at the climax of its multiplication the cells are destroyed. Instead of the ring of living cells about each fragment of tissue, all that can be seen is an ill-defined zone, containing the granular debris of dead and dying cells. And it can be shown that the fluid phase of the culture now contains more virus than before.

Cultured tissues are in general susceptible to the same viruses as the animals from which the tissues have been taken; thus we find that only tissues from man, monkey or chimpanzee will grow polio virus. But within one species this general rule does not apply. In intact monkeys or humans, polio virus is extremely fastidious in its choice of suitable cells, there being only two main places within the body where it is able to multiply. The first of these is the digestive cavity; the other site is certain cells in the nervous system. In tissue culture, however, cells from the skin, the kidney, and the testicle will all support the growth of polio virus. We do not know why cells should behave in this odd way when out of their normal environment, but the fact that they do explains why Enders and his fellow workers were able to grow polio in non-nervous tissues.

Besides their use as virus detectors, tissue cultures can also be used to show the presence of antibodies to polio virus in a person's blood. An individual who has been infected by polio virus generally has antibody against the virus in his blood. This is so whether he has had a paralytic infection, or whether he has merely been carrying the virus in his gut without outward signs of infection. So widespread is the virus in nature that almost all adult persons have this antibody, evidence that at some time or other they have been infected by polio virus. If a blood serum containing antibody to polio virus is mixed with the virus itself, and the mixture put into tissue cultures of the kind described above, the virus will fail to grow, and the cells will not be killed; the antibodies neutralise the virus, and protect the cells from its evil effects.

Tissue cultures can thus be used both to look for virus and its antibody on a scale whose cost would be prohibitive if monkeys had to be used instead for these purposes. One of the most suitable tissues for growing polio virus is monkey kidney. Every monkey has two kidneys, and each of these will provide about 250 cultures. Each culture provides as much information as one monkey did in the old days, so that one monkey now does the work of five hundred. The scale of research can correspondingly be multiplied.

A further consequence of the work of Enders and his colleagues is of far more direct importance with regard to the immediate control of poliomyelitis. The virus grows particularly vigorously in cultures of monkey kidney cells, and when the cells are destroyed large amounts of virus are set free into the fluid phase of the cultures. This virus can readily be treated with formaldehyde in such a way that it loses its ability to infect monkeys or further tissue cultures, but nevertheless retains its power to cause the production of antibodies when injected into animals or men. The tissue culture method thus makes it possible to produce a vaccine which can then be tested as a possible immunising agent against poliomyelitis. Such a vaccine, produced from virus grown in tissue cultures has recently been tried out on a large scale in the U.S.A., and we hope to hear the results in 1955.

On the research side further discoveries, all directly traceable to the initial stimulus of the work of Enders and his collaborators, are already being announced, although it is less than four years since these workers announced the first results they obtained by applying their new technique.

One of these has been the growth of polio virus in a strain of human cancer cells which can easily be maintained alive in large numbers for long periods by workers without a specialised training in tissue culture, thus almost bringing the virology of poliomyelitis within the reach of the ordinary hospital laboratory. Another has been the development of an ingenious technique for counting individual particles of polio virus. The virus sample is spread out over the surface of a large sheet of growing monkey kidney cells. Where each particle lands, it grows and destroys the nearby cells, revealing its presence by a 'hole' in the sheet of cells. The number of these holes is equal to the number of active virus particles originally present.

It is thus difficult to overrate the importance of Enders, Robbins and Weller's discovery. Not only has it vastly expanded the scope of poliomyelitis research, but it has also provided, almost at one stroke, the means for producing a vaccine in the vast quantities required for an adequate test. And in addition there is the stimulus it has given to further research. There need be no doubt that this Nobel Prize was richly deserved.

# THE PROBLEMS OF COLOUR TELEVISION

GEOFFREY PARR, M.I.E.E.

*In the past few months demonstrations of experimental colour television have been given by two British manufacturers, and a colour television service has been forecast by the B.B.C. within two or three years. This article describes some of the difficulties which have had to be overcome in the initial stages of developing a satisfactory commercial colour system.*

*Let it be required to ascertain the colours of a landscape by means of impressions taken on a preparation equally sensitive to rays of every colour. Let a plate of red glass be placed before the camera and an impression taken. The positive of this will be transparent wherever the red light has been abundant in the landscape and opaque where it has been wanting.*

*Let it now be put into a magic lantern along with the red glass, and a red picture will be thrown on the screen.*

*Let this operation be repeated with a green and a violet glass, and by means of three magic lanterns, let the three images be thrown on the screen superimposed. The colour of any point on the screen will depend on that of the corresponding point of the landscape, and by properly adjusting the intensities of the lights, a complete copy of the landscape as far as visible colour is concerned will be thrown on the screen.*

These words of Clerk Maxwell's, written in 1855, still serve with suitable modifications, to describe the principles on which colour television is based. The colours of the filters have been changed to red, blue and green, and the cathode-ray tube has replaced the magic of the lantern with greater magic, but the method of colour analysis into three primary colours is fundamental.

The blending of the three primary colours, red, green and blue, to give the sensation of any colour in the spectrum has been reduced in modern times to a formula of deceptive simplicity in which any colour $C$ may be expressed in terms of coefficients of three primary colours

$$C = ax + by + cz$$

where the components $x$, $y$ and $z$ can be determined from a so-called 'chromaticity chart' (Fig. 1). This diagram, which has been developed from an original proposal by Clerk Maxwell, expresses the wavelengths of the spectrum colours in rectangular co-ordinates $x$ and $y$, $x$ corresponding to red, $y$ to green, and $z$, the value of the blue component, being found by subtracting the sum of $x$ and $y$ from unity. This diagram provides the means of obtaining quantitative values of the components which can be specified accurately with relation to the composite white light formed by mixing the three primaries together. In turn, this quantitative value can be transformed into terms of energy, voltage or any convenient quantity.

The first step in transmitting a given colour is therefore to analyse it into the three values of primary colours which compose it, and then to send signals corresponding in amplitude to each of the three components. These signals can then be recombined at the receiving end to reproduce the sensation of the original colour, given a suitable means of converting the electrical impulses into coloured light.

Fortunately it is not necessary to send the signals simultaneously in the strict sense of the word, as, provided that the rate of presentation is sufficiently rapid, the eye will blend the individual components by persistence of vision just as it perceives smooth motion from the rapid succession of still scenes in the cine film, or the flying spot of the television tube.

A method of transmitting successive pictures in each of the three primary colours was demonstrated by J. L. Baird as long ago as 1928 (Fig. 2), following his practice of exploring every possible development of his new wonder, television. Apart from the crudity of the picture at that time, the system was not commercially practical for reasons that were adduced in later years, although it was based on the sound principles of Clerk Maxwell.

The original scene was scanned through a rotating disc carrying three filters in the three primary colours, and a similar disc ran in synchronism in front of the receiver screen. The complete picture was scanned in each of the three primaries in turn and was thus made up of three-colour 'fields' superimposed in rapid succession. This method of transmission became known later as the 'field-sequential' system.*

One of the disadvantages of the field-sequential system is that in order to obtain the same definition as a monochrome picture and avoid flicker, the scanning process has to be speeded up so that the three colour fields are received in the same period as that of the monochrome picture. It has already been established that the repetition rate of a monochrome picture requires to be at least 50 per second for satisfactory images and the colour repetition rate would therefore have to be 150 fields per second—a threefold increase in frequency.

This brings us to one of the cardinal problems of colour television: the band of frequencies involved in its transmission. This problem is of such importance that no excuse is made for restating the elementary principles involved in transmitting television frequencies.

Assuming that a monochrome picture is composed of alternate squares of black and white (Fig. 3), the signal current will pass through a complete cycle as the scanning spot moves from black to white and black again. The number of black and white alternations will therefore determine the maximum frequency of the signal transmitted. In the B.B.C. standard transmission, the picture contains 377 effective lines (28 of the total of 405 are black lines) and each line is scanned in an effective time of

* The word 'field', as used in television, applies to part of the complete scanned picture. In Britain the picture is considered as made up of two interlaced 'frames', but in America these frames are called 'fields', and the word 'frame' refers to the complete picture. It seems preferable to conform to American usage, which is in agreement with the terminology used in cinema practice.

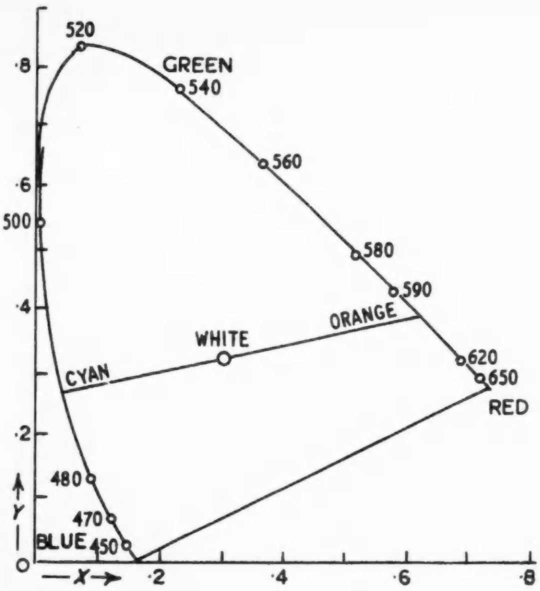



FIG. 1. Chromaticity diagram, giving quantitative values of the primary components of a given colour.

80 microseconds. The proportion of the picture is 4:3 horizontally, and the number of elemental squares in each line is therefore

$$\frac{4\times 377}{3},$$

if each square is equal in depth to the thickness of a line.

The frequency of alternation of the signal is given by dividing this figure by the time to scan one line and by 2 (since one complete cycle corresponds to scanning 2 squares). The grand result is

$$f=\frac{4\times 377}{3\times 2\times 80} \text{ or } 3{\cdot}1 \text{ megacycles per second approx.}$$

This means that the circuits associated with the picture transmission and reception must be capable of responding to all frequencies within a band of about 3 megacycles without distortion or attenuation.

Considering the radio-frequency transmission, the carrier frequency of the London transmitter is 45 megacycles/second for the vision signal and 41·5 megacycles/second for the sound. The total band occupied by the vision frequencies is therefore (45+3) to (45−3) and the total band-width required is 41 to 48 megacycles/second allowing a slight no-man's-land at the lower end of the band (Fig. 4*a*). If each element of the picture required three colour components to be transmitted in the same overall period of time the frequency band of the transmission would be increased threefold (Fig. 4*b*), a requirement which would still further congest the already fully occupied ether.

One of the essentials of a successful colour system is,

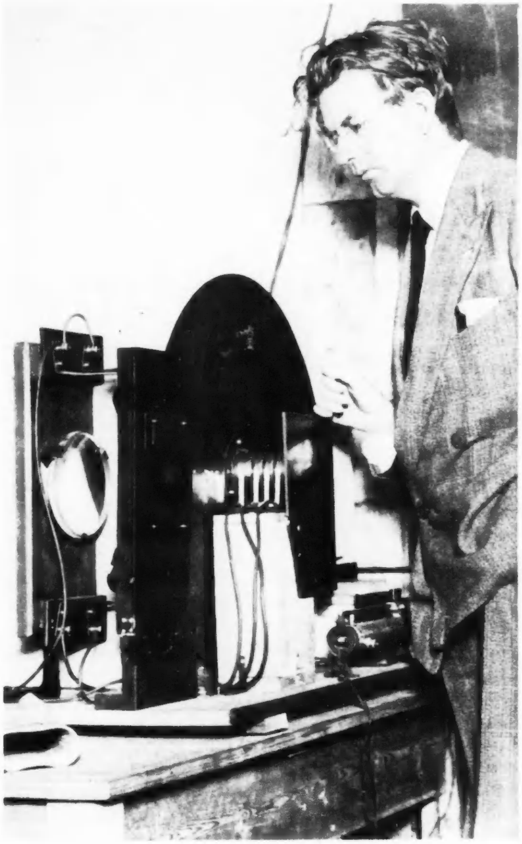


FIG. 2. J. L. Baird with his experimental colour receiver, 1928.

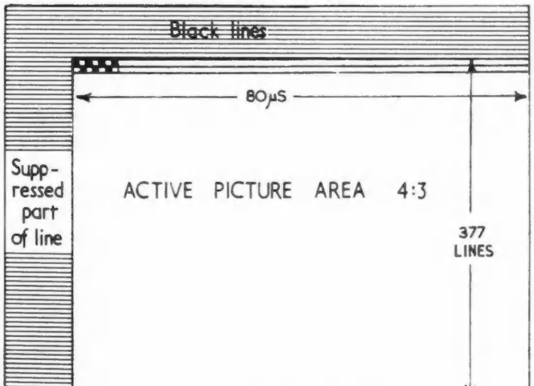



FIG. 3. The B.B.C. standard television picture, showing how the maximum frequency of signal is calculated.

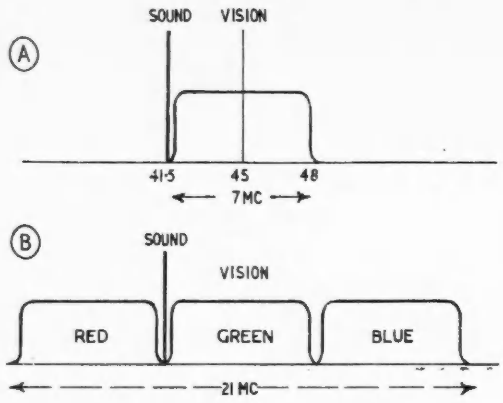



FIG. 4. Band-width of monochrome transmission (*a*), and band-width required for field-sequential colour system (*b*).

therefore, that it shall not make impossible demands on the frequency bands allocated for television broadcasting.

Ignoring for a moment this limitation, the possibilities of the rotating colour filter system seemed at one time very encouraging, and the Columbia Broadcasting System spent many years in developing it to a high degree of efficiency under the direction of Dr. Peter Goldmark. In this country satisfactory systems were also developed for closed circuit demonstrations (where the radio frequency limitation did not enter) and special transmissions not involving the normal broadcast frequency bands. A notable achievement was the televising of the Coronation in colour by Pye Ltd., the pictures being shown on receiver screens installed at the Children's Hospital in Great Ormond Street. The link between the transmitter and receiver in this case was a radio beam transmitter operating at a frequency outside the television band.

There are, however, other disadvantages of the rotating filter system which preclude its use as a basis for a complete colour system. There is the drawback of introducing a mechanical component into an otherwise all-electronic system, and the limitation on the size of picture imposed by the diameter of the rotating disc. At the receiver end this disadvantage can be overcome by using a special cathode-ray tube, but there are inherent troubles which cannot be avoided by any ingenuity in component design. The nature of the system introduces into the picture a form of colour distortion in which rapidly moving objects are followed by colour fringes as they traverse the screen.

Secondly, as was shown later, the simple rotating filter system is actually wasteful of frequencies in the transmission band, since it is not necessary to transmit full detail in each of the three primary colours in order to obtain an acceptable picture. Finally, there is the difficulty of designing a system which would fit in with the existing monochrome standards—an important consideration in America where the number of receivers had grown to millions in a very short time.

The Radio Corporation of America, who had entered the colour television field soon after the end of the war, decided that the only future of colour lay in an all-electronic system which would be compatible with existing monochrome standards. The term 'compatibility', which has been often used in discussing colour systems, implies that the colour signal must be capable of giving a satisfactory picture on monochrome receiving tubes.

The first experimental R.C.A. system utilised three cameras, each with a filter to give one component of the tricolour signal, and three reproducing tubes each giving a picture in one of the primary colours. The three pictures were combined by means of an optical system in the receiver (Fig. 5). The standards chosen conformed to the existing monochrome standards, the 'green' channel being used for monochrome transmission. The system was therefore compatible, although the band-width required for the transmission was 12 megacycles/second.

The problem of reducing the band-width required for the transmission still remained to be solved, although a pointer to future developments was made by A. Goldsmith in 1940. He showed that the blue component of the signal could be reduced in amplitude without degrading the quality of the picture. The eye has less acuity for blue, and it would thus be possible to dispense with the blue component for small areas, provided that the brightness of the area and the remaining colour components were in the correct proportions.

In 1945 Willner and Knight showed that the colour of these small areas could be accurately rendered by using only two primary components of orange-red and blue-green ('cyan'), to which the eye is more sensitive when detecting small differences of colour. In effect, when the detail of the coloured picture is sufficiently small, the colours can be approximately represented on the chromaticity chart (Fig. 1) by a line joining the orange-red and cyan values.

A further point, noted by A. V. Bedford, was that in the extreme case of small details approximating to one or two picture elements in size the colour became an indeterminate greyish-yellow, and the eye, in studying this detail, relied mainly on differences of brightness rather than of hue.

These investigations had a profound effect on the development of an economical colour system, as it was obvious that the transmission of three fields in full primary colours contained a great deal of unnecessary information and some of the information although necessary, was duplicated.

The simplification of the colour transmission system, if the electronic complication which followed could be called simplification, was based on the following data:

1. As the brightness of the picture was an all-important factor which affected the rendering of both small and large areas, it should be transmitted as a separate component of the colour signal.
2. For areas of average size in the reproduced picture it would be necessary to transmit all three colour components.
3. For small areas it is only necessary to transmit two colour components.

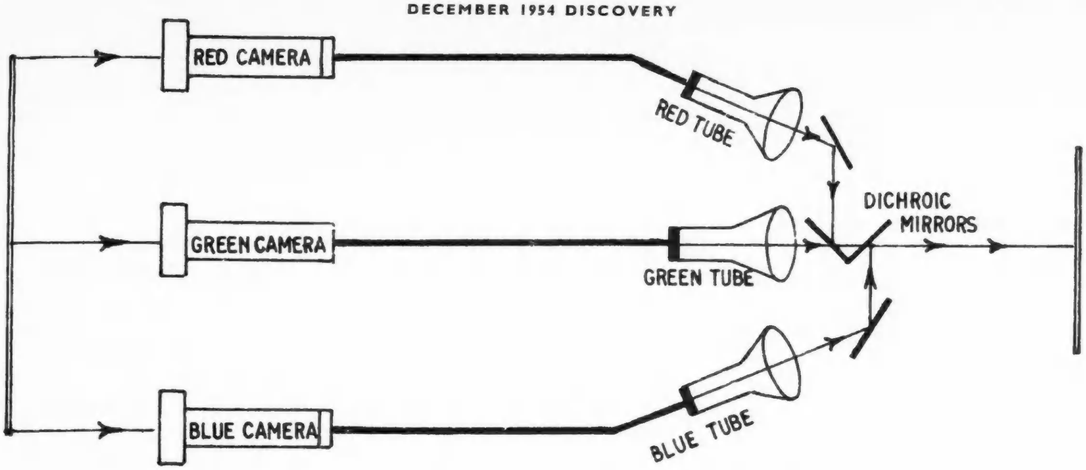



FIG. 5. Reproduction of colour picture by superimposing three primary images.

4. For very small areas it is only necessary to transmit the brightness component, and the colour component can be ignored.

Turning these requirements into terms of frequency of signal, we can consider the timing of one scanning line in the British system, as was shown in Fig. 3. As an approximation in round numbers, one line of the picture is scanned in 1/10,000th second, and on a picture measuring 10 inches across, an inch length of line will give rise to a signal of 1/100,000th second duration, i.e. a frequency of 0·1 megacycles/second. A small detail can be considered as occupying 1/10th inch, and the corresponding frequency will be 1·0 megacycles/second. A detail comparable with the size of the picture element will give rise to a frequency of 3·0 megacycles/second.

Provided, therefore, that some means can be found of transmitting the colour signal frequencies within the normal band-width, it is possible to devise a colour system which will not occupy any more space in the ether than a monochrome system. The method by which this has been accomplished is a triumph of electronic ingenuity by the R.C.A. engineers, and although it is not altogether free from flaws it has stood up to practical tests outside the laboratory with very satisfactory results.

## THE COLOUR SIGNAL

Before discussing the method of compressing the signal frequencies into the allotted band-width it is convenient to start at the transmitting end and see the nature of the composite signal which is handled by the transmitter. The diagram of the camera and amplifiers is shown in Fig. 7.

The scene is analysed into the three primary components by filters in front of each camera, and the signals are passed through a mixing, or matrix, amplifier. Here they are mixed to produce a synthetic 'white' signal, which gives the brightness ('luminance')* component of the coloured

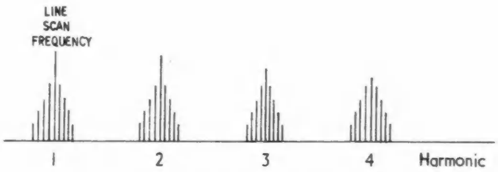



FIG. 6. Distribution of frequencies in monochrome television signals.

scene. The proportions of the colour components in the luminance signal are not, as might be thought, equal but are mixed according to the formula

$$0{\cdot}3\ \text{Red} + 0{\cdot}59\ \text{Green} + 0{\cdot}11\ \text{Blue}.$$

The reason for this is that the eye is not equally sensitive to all colours, and these contributions are in direct proportion to the 'brightnesses' of the chosen primaries, as seen by the eye.

This brightness signal, which is called the 'Y' signal, contains all the frequencies up to the maximum in the allocated band—in the British system 3 megacycles/second, in the American 4 megacycles/second. It is therefore suitable for reproducing a picture on a monochrome receiver, thus fulfilling one of the requirements of the American Federal Communications Committee that the system should be compatible.

It should be noted that the signal, on leaving the camera, actually contains both the brightness and colour information about a given area of the picture. Having obtained the brightness signal by mixing the three colours, it is not therefore necessary to transmit it again with the colour signal. Accordingly the colour signal only contains information about the quality of the colour, i.e. its hue and saturation.

In the subsequent amplifiers the contribution of each colour signal to the brightness is removed, and that which

* Although 'luminance' is the correct term for this component, the word 'brightness' is used synonymously, as it is more familiar to users of television receivers.

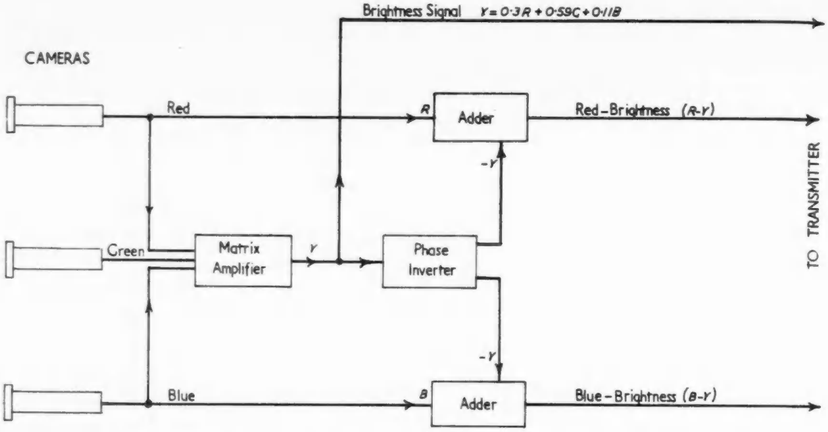



FIG. 7. Schematic diagram of RCA colour television system—transmitter end.

remains is handed on as the colour component. Referring to the diagram, the 'Y' signal is reversed in polarity by the phase inverter, and removed from the red and blue signals in the adder stages, giving two emerging signals of red minus brightness and blue minus brightness. The green signal is not handled in this way, as will be explained later.

To those who find it difficult to divorce brightness from colour in this way, it is only necessary to say that the quantities are dealt with in terms of voltage, and if the output signal contains $(a + b)$ volts it is a comparatively easy process to subtract $b$ volts corresponding to the brightness component, leaving $a$ volts corresponding to hue and saturation of the colour. This voltage concept is important in understanding the operation of the colour system, since it enables the value of any component to be obtained from the others by simple subtraction. This is precisely how the green signal is handled.

Referring to the formula given above for synthetic white, the total voltage at a point in the circuit may be 0·59 + 0·3 + 0·11, or 1·0 volts. If we subtract 0·41, representing the red and blue volts, the remainder must be equivalent to the green signal. This resolves into a further saving in the amount of information transmitted, as, in order to enable the three primaries to be recovered at the receiving end, it is only necessary to transmit the brightness signal and information about two of the primaries.

The reconstitution of the colour information at the receiver is shown in Fig. 8, where the three composite signals from the transmitter are shown coming in on the left. Both the red and blue colour signals are added in an amplifier stage to give the missing green signal, which emerges as 'green minus brightness' (G−Y). The three colour components then pass through adder stages where the brightness is restored to each, and finally the complete colour signals are applied to the reproducing tubes (shown as separate units in the diagram).

Since the whole accuracy of the colour rendering depends on the mixing of the two-colour signals, a defect in the circuit will produce interesting variations in the appearance of the reproduced picture. For example, with the (B−Y) component missing, the red of the original scene will be reproduced as magenta, the green will become paler and the blue will become green. If the colour controls are accessible to the viewer they will enable him to relieve the monotony of an occasional dull programme.

## BAND-WIDTH COMPRESSION

The requirement of the colour system is that it shall occupy no more band-width than an existing monochrome channel, and the colour information must therefore be inserted in the brightness frequency band-width.

The method by which this is done is perhaps the most ingenious of the many ingenious dodges used in colour television, and involves the old problem of multiplexing, or transmitting more than one series of signals over a transmission system without confusion. The principle involved is that of time-sharing, in which the independent signals occupy separate periods of time in the transmitting channel. Provided that some form of synchronising is used at the transmitter and receiver, it is possible to combine the signals during transmission and separate them at their destination.

In applying this principle to colour signal transmission, advantage is taken of the known observation that in monochrome television the majority of the information is transmitted by frequencies which are closely associated with harmonics of the line scanning frequency. A histogram of the distribution of this information would appear as shown in Fig. 6, leaving gaps in the frequency spectrum which are only occasionally invaded by stray signal frequencies.

This offers a possible means of transmitting the colour information by inserting it in the gaps left in the frequency spectrum after the brightness signals have been accommodated. These gaps correspond to frequencies which are odd multiples of half the line frequency.

Accordingly, a carrier frequency for the colour is selected so that it, together with its side-band frequencies, occupies the gap in the frequency spectrum. This so-called 'frequency interlace' gives rise to a certain amount of cross-talk or interference between the signals which makes it difficult to separate them completely, but the interference

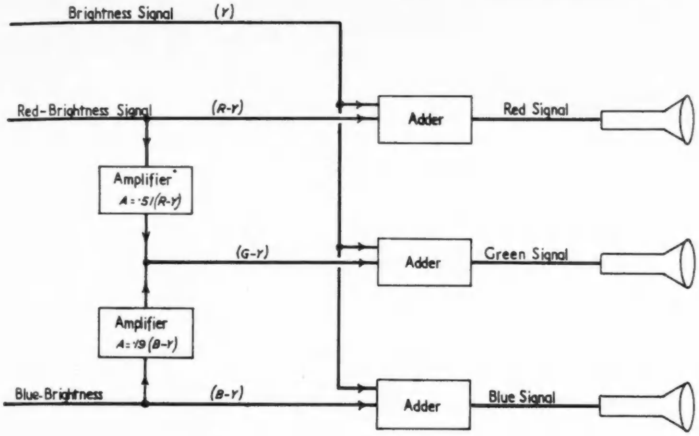



FIG. 8. Schematic diagram of RCA colour system: receiver end. Note the production of the green signal from the red and blue signals.

can be greatly reduced by careful design of circuits and choice of carrier frequency.

It is necessary to modulate the colour sub-carrier with the two components mentioned above—one corresponding to the degree of saturation of the colour and the other corresponding to the hue. The method of modulation used results in a single sub-carrier of which the amplitude is varied by the saturation and the phase is varied by the hue (Fig. 9). At the receiving end it is important that the phase change is accurately interpreted, or the wrong hue will result. To provide the necessary locking between receiver and transmitter, a local oscillator is included in the receiver circuit and tuned to the sub-carrier frequency. This oscillator is kept in synchronism by a short burst of signals at the sub-carrier frequency which is transmitted as part of the main picture synchronising signal (Fig. 10).

The reader, if he has followed thus far, has probably taken in enough to realise the enormous complexity of the system which undertakes to transmit colour signals compressed into a comparatively narrow band, and will sympathise with the writer who attempts a similar feat of compression in describing the system. Before considering any possible simplifications, we can turn to the receiver and consider the ways of reproducing the colour information in the form of an acceptable picture.

As said previously, a monochrome receiver will have no difficulty in reproducing a picture from the colour transmission as it will contain no decoding circuit for the colour signals and will respond only to the brightness signal. Conversely, a colour-reproducing receiver will show a satisfactory monochrome picture from a monochrome transmission, since there are no colour signals present to affect it: The only requirement in this case is the ability of the colour-reproducing tube to give a uniform white screen in the absence of colour signals. The system therefore fulfils the requirement of being compatible both ways.

As said at the beginning of this article, the reproduction of coloured pictures by superimposing three separate primary images is a 'known art' which only requires extreme precision in registering the images. With modern technique this method has been used by mounting dichroic mirrors* in front of the three cathode-ray tubes, as shown in Fig. 5. It can be applied to both the receiving end and the transmitting end, although a three-tube camera with its associated equipment is a costly and weighty unit.

An improvement in the reproducer was made by combining the three tubes in one, or, rather, combining the three electron guns in one tube (Fig. 11). The screen of this tube is then coated with a regular dot pattern composed of three kinds of fluorescent material, giving red, green or blue fluorescence when excited by the electron beam.

Between the electron guns and the dot-patterned screen is a mask containing a series of holes, each hole covering one set of three dots. The electron beams from the three guns are guided through the holes in the mask so that each beam only excites one of the three dots. The incoming colour signals then modulate the beams to produce corresponding fluorescence in the dots, and the picture is effectively made up of a number of tiny triangles in the three primary colours. The size of the dots is only 0·014 inch and the number on the face of the tube is 600,000, enough to reproduce the fine detail of the picture. Another form of multi-element screen, due to Lawrence, has the fluorescent material in the form of thin strips. A series of parallel wires in front of the screen acts as a mask, and the deflecting potential applied to the wires deflects the electron beam on to the appropriate colour on the screen.

* Mirrors which transmit one colour while reflecting another colour.

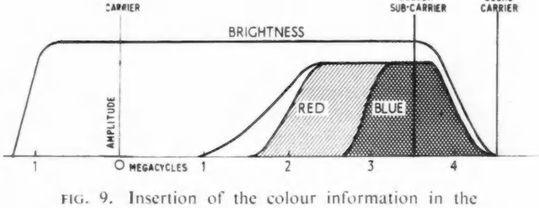



FIG. 9. Insertion of the colour information in the band-width of a monochrome system by using a colour sub-carrier.

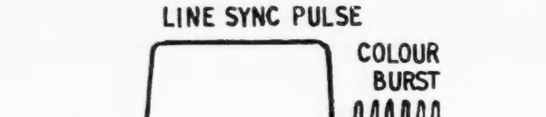



FIG. 10. Additional synchronising signal required for colour transmission, inserted in the line synchronising signal.


FIG. 11. Principle of the colour-dot tube with three electron guns (RCA).

The cost of producing colour tubes of the dot- or line-element type is one of the main factors in determining the economic price of the colour receiver, as, apart from the initial outlay, the viewer will hesitate at paying almost the price of a monochrome receiver for a replacement tube.

## BRITISH DEVELOPMENTS

The problems of colour television are no different in this country, although the B.B.C. standards differ from American practice. The compatibility of a new colour system does not perhaps assume such importance, as the number of receivers is considerably less and there are more channels available for alternative systems.

As a speaker said at a recent discussion at the I.E.E.: "The introduction of a colour system will be the last chance for a revision of television standards for some time, and future monochrome and colour systems should be considered together for a new system." One of the possibilities would be to use the 625-line system as in America, with arrangements for converting the signal into a 405-line standard for existing receivers. Television engineers in

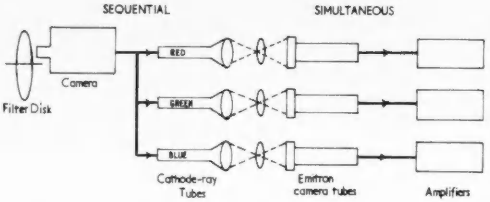



FIG. 12. E.M.I. 'Chromacoder' system, employing field-sequential camera with conversion to simultaneous signals by separate Emitron tubes.

Britain have already had considerable success in converting from one standard to another, as shown by the Eurovision broadcasts, and this conversion might enable the colour system to be utilised by existing monochrome receivers.

The discoveries made on the colour composition of small details have already been made use of in simplifying the camera unit. The Marconi Company have produced a two-tube camera which is very little bigger than the monochrome camera. One tube produces a high-definition monochrome picture of full frequency band-width, and the other tube gives two lower definition colour signals corresponding to the cyan-orange colours previously mentioned. In the system that they propose the colour information is not transmitted within the main channel as a sub-carrier, but is given a separate carrier. This obviously results in an increase in the total band-width occupied by the transmission, but, unlike the American systems, we can afford to take a little more room in the ether.

Mention must also be made of the system of colour pick-up recently demonstrated by Electric & Musical Industries. In this system it is recognised that the simplest and most effective method of scanning in colour is by using a rotating filter disc in front of the ordinary pick-up camera, the field-sequential system. To maintain the economy in band-width in transmission the field-sequential system is converted immediately into a simultaneous system by making use of intermediate cathode-ray tubes (Fig. 12). The images reproduced on the tubes are focused on to three Emitron pick-up tubes which produce the simultaneous signals for mixing and handing on to the transmitter.

This system has also been utilised in America under the name 'Chromacoder', although it is worthy of note that the tubes used are of British manufacture.

With a simplification of the camera unit and freedom from some of the restrictions imposed by band-width limitations, it is possible that the British colour television system may be introduced with greater economy and less trouble than appears after reading this survey, but we should be wanting in gratitude if we did not acknowledge the pioneer work which was done by American engineers during the early days of the war when we were, unfortunately, otherwise occupied.

# THE FRENCH ENCYCLOPEDIA AND THE INDUSTRIAL REVOLUTION

A. D. CUMMINGS, M.Sc., Ph.D., F.Inst.F.

On July 1, 1751, there appeared the first volume of the great French Encyclopedia, a work which was destined to have far-reaching results in more than one sphere of human affairs. It was the first modern encyclopedia, and was unique in its period since it attempted to embrace all branches of knowledge. It dealt not only with history, philosophy and literature, but gave a detailed coverage of science and technology such as had not been seen before except in a few monographic works such as the classic metallurgical work entitled *De Re Metallica*. No previous encyclopedia had approached in scale the conception of Diderot which finally materialised as a 35-volume opus.

Many of the most important French scientists contributed to this encyclopedia—such men as Buffon, Daubenton, Haller and Condorcet, and during the first few years of its compilation d'Alembert assisted Diderot as co-editor besides writing a number of entries on various scientific subjects.

No less impressive were the contributions on technological subjects; the coverage of industrial arts and crafts was remarkably comprehensive, and equally impressive was the exhaustive treatment given to each and every technical subject included in the encyclopedia. In this connexion it is apposite to quote Lord Morley's famous remark: "In all the chief departments of industry there are plates good enough to serve for practical specifications and working drawings . . . [Diderot] actually took the pains to make it a complete storehouse of the arts, so perfect in detail that they could be at once reconstructed after a deluge in which everything had perished save a single copy of the Encyclopedia." Much has been written about the part played by the French Encyclopedia in the political movement leading to the French Revolution; it is no exaggeration to say that the work was equally important for the impetus which it gave to the Industrial Revolution in Europe.

In the later stages of the Industrial Revolution Britain was well ahead of all her European rivals, but at the outset, when that revolution was just beginning, her position was just the reverse. In applied science, England lagged behind Europe until the latter part of the 17th century; then she began to catch up, and by the middle of the 18th century Britain had drawn ahead. Thus we find that after the conclusion of peace between England and France in 1745 the French Government sought and obtained permission to send an investigator, M. Jars, here to report on our technical advances. Of special interest to him was the English technique for making iron with coke instead of charcoal. Not much about those advances had been recorded in books; perhaps we in Britain were too busy in our factories to spare the time to put on paper the details of the new developments. Detailed descriptions of English manufactures in the 18th century are far from abundant, and for that reason Jars' book (*Voyages Metallurgiques*, 1764) remains a mine of information for anyone interested in the technology of that period.

The demand for reading matter dealing with methods of manufacture and similar matters must certainly have been small compared with the modern demand for such information, but the demand for such literature probably far exceeded the supply. That was the situation which prevailed at the time when Ephraim Chambers, an English Quaker (1680–1740), published by subscription his two-folio *Cyclopedia, or Universal Dictionary of Arts and Sciences*, which first appeared in 1728. (Ephraim Chambers was no relation of W. and R. Chambers who later started the famous Edinburgh publishing firm.) A French publisher, Le Breton of Paris, approached Chambers about a French edition of his encyclopedia (which incidentally was more like a modern technical dictionary than a modern encyclopedia), and arranged with an Englishman called Mills, to translate the book. The French edition was announced in a prospectus, but it never materialised.

Le Breton then had the idea of getting Diderot to produce an encyclopedia which would represent an expansion of Chambers' encyclopedia; to quote Lord Morley's *Diderot and the Encyclopaedists*, Diderot's "enthusiasm fired Le Breton. It was resolved to make Chambers' work a mere starting-point for a new enterprise of far wider scope."

The very first prospectus which was sent out to possible subscribers to Diderot's encyclopedia mentioned Chambers' dictionary, and implied that material from that dictionary would be incorporated in the work. When the first volume appeared, no mention at all was made of Chambers on the title page, which bore these words:

> ENCYCLOPEDIE, ou Dictionnaire raisonné des sciences, des arts et des métiers, par une société de gens de lettres. Mis en ordre et publié par M. Diderot et quant à la partie mathématique par M. d'Alembert. Paris 1751.

The famous encyclopedia kept Diderot fully occupied for twenty years, until in 1765 he was able to write to Voltaire (who was a contributor) "*le grand et maudit ouvrage est fini*". He brought to the work an enduring enthusiasm that surmounted all the many obstacles he encountered—there was the opposition of the clergy, the defection of his co-editor d'Alembert before the work was half finished, and the secret censorship of Le Breton, who took fright when the encyclopedia came under fire and proceeded to cut out passages from the volumes still in process of printing which he thought might cause trouble.

The use of the French Encyclopedia as a platform by the most eminent liberal authors of the day and its part in bringing about the fall of the *ancien régime* are too well known to require any comment. The work abundantly fulfilled the promise of the original prospectus, which

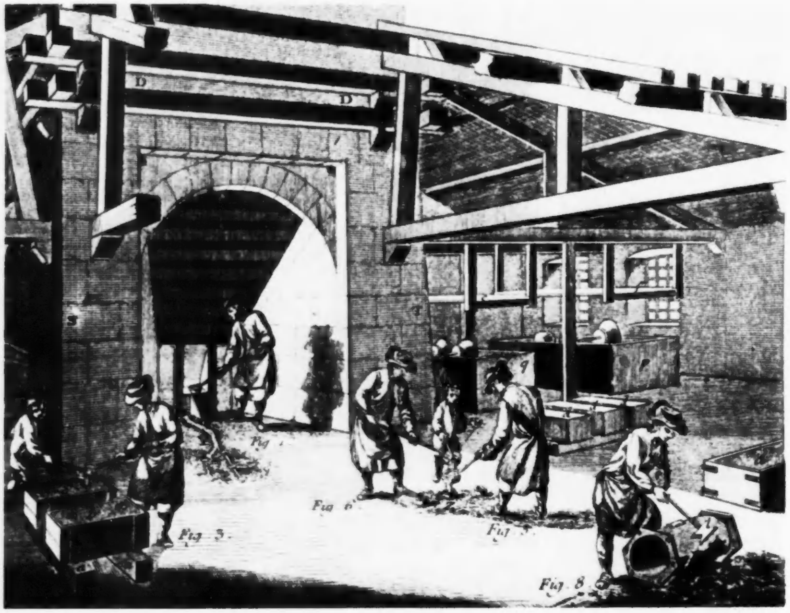


FIG. 1. This picture from Diderot's Encyclopedia is a scene in an 18th-century ironworks: it shows the making of small iron castings, with a melting furnace in the background.

recorded the editors' intentions to describe the mechanical arts of the times; in this field, said the prospectus, recent advances had rendered out of date the few extant descriptions; "too much has been written about science, but not enough about the liberal arts and scarcely anything about the mechanical arts". Diderot himself wrote many of the articles about manufactures; he also deserved particular credit for organising what was a unique feature of the encyclopedia, the lavish illustrations. Of the original issue of 28 volumes, eleven were devoted to illustrations, and nearly all the three thousand plates were full-page plates measuring approximately 12 in. by 17 in. Diderot is reputed to have gone into factories and workshops himself to see how the various processes worked, and to have learnt to work the machines himself so that he would be able to describe them accurately. From the evidence of the plates and accompanying descriptions it is certain that the authors, the artists and the workpeople must have collaborated closely. The artists probably made a number of quick sketches on the spot, selecting those operations which would show the essentials of a process. After discussion with Diderot, these could be worked up into the finished copperplate engravings. As a result we have preserved a faithful record of how things were made 200 years ago. Not only that, but we feel we know the lives of the people better than many pages of description could tell us. Diderot says that many methods are "*facile à prendre mais très difficile d'expliquer*", and these have been illustrated as fully as possible.

The encyclopedia was issued at the dawn of the Industrial Revolution. The "Fire Engine" appears in it, under Hydraulics, but it is not particularly noted as important and indeed the only source of power in any of the factories mentioned is a waterwheel. Most of the processes illustrated in the encyclopedia are hand-worked for the greater part, but some of the machines that are shown are quite complicated, though all of them are made of wood.

Some of the best illustrated sections in the encyclopedia are as follows:

*Art militaire* (troop movements, fortifications), 38 plates.
*Forges, l'Art de Fer* (iron smelting, casting and wrought iron), 51 plates.
*Glacerie* (making and polishing mirrors), 47 plates.
*Manège* (horsemanship), 33 plates.
*Marine* (shipbuilding—an excellent section), 37 plates.
*Serrurier* (lock making), 57 plates.
*Tourneur* (wood turning), 87 plates.
*Verrerie* (glass making and working), 69 plates.
*Soierie* (silk weaving), 135 plates.

There are only two plates showing coal-mining operations, and very few are devoted to chemical manufactures; this is not surprising, of course, for these industries did not reach their full importance until the next century.

A great deal of technical information is conveyed by the plates; a typical example is provided by the pictures illustrating the section on iron-making which show the following operations: getting the ore, both by underground and surface workings (the men shown at work wear knee breeches and those turning a windlass wear three-cornered hats; boatmen are seen recovering ore with nets from shallow lakes); the crushing and washing of the ore in water-driven machines; plans, sections and outside views of blast furnaces (using charcoal, not coke); casting large cooking pots, water pipe sections and large pigs (14 ft. long)—women are shown working in both moulding and casting shops, men fill the ladles, which are poured by women and boys; making wrought iron from pig iron by

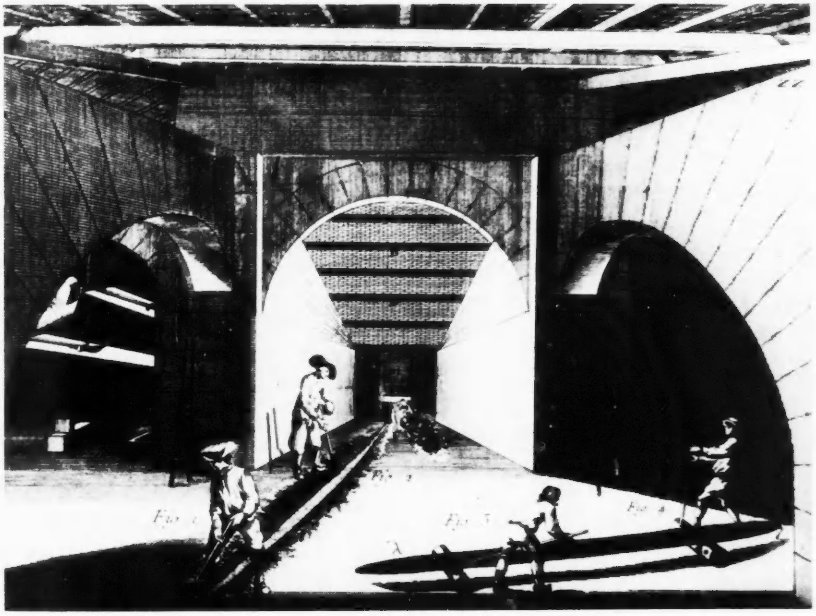
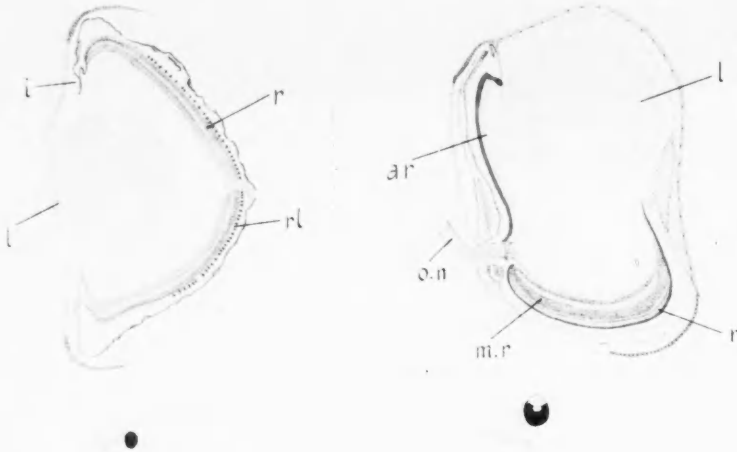


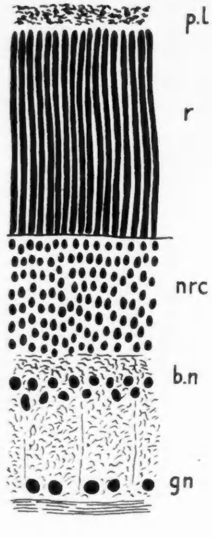
FIG. 2. Another picture from the Encyclopedia of a contemporary ironworks; we see preparations being made to tap a blast furnace.

repeated heating and hammering under a large water-operated hammer; making iron rod by passing heated bars through water-driven rollers.

The inspiration to treat working processes so fully in this way may have come from another collection then in progress, if progress is the right word for such a leisurely performance. As far back as 1675, the founder of the French Academy of Sciences—Colbert, Minister to Louis XIV—had suggested to that academy that they should collect together descriptions of "*machines en usage dans la pratique des arts*" for the betterment of French industry. Perhaps the academy thought that industry was not its province, but for some reason or another Colbert's idea was not acted on with any great expedition; by 1708, when Réaumur was put in charge, the total achievement was but one work on printing. Much later we find Réaumur accusing Diderot of stealing plates for the encyclopedia that were intended for the academy's collection. Owing to the bad faith of his engravers, said Réaumur, and the unscrupulousness of some people, he had been robbed of the toil of many years. Presumably he meant that drawings he had commissioned, and which were still in the artists' hands, had been offered to Diderot when he began to make inquiries about such things. The academy inquired into the affair, but as Réaumur's charge against Diderot was never repeated we may assume that the drawings or plates came into his hands honestly. In any event, his collection soon outstripped the academy's.

We today may feel grateful to Diderot and all those who encouraged him to persevere against difficulties; amongst them was Madame de Pompadour. He preserved for us a splendid set of records of processes that have since died out or altered greatly. And yet artisans and craftsmen of the present day will, in seeing these 18th-century people at work, recognise their close kinship with them, for the way of handling tools and the performance of many hand operations remains fundamentally the same. The encyclopedia describes the limit reached by industry before the advent of steam power and before the clumsy wooden machines were replaced by more compact iron ones. Without some other motive power than flowing water, limited as it was in amount and location, industry could expand no further. Shortly after the final volumes of the encyclopedia appeared, Watt's steam engine materialised, and the Industrial Revolution entered a new phase. Many mechanical arts and industrial processes had been developed to their practical limits in the pre-steam age; once steam power became available it was possible to visualise a 'quantum-jump' forward in the efficiency of such processes. The advances which Watt's steam engine made possible could be visualised more clearly because of the existence of Diderot's encyclopedia which recorded in vivid detail the technique of key industrial processes in their contemporary state of perfection. The encyclopedia must have prompted many men to say, "I could manufacture this or that thing here; I have the raw material . . . but there is no stream to drive the mill, so it cannot be done." Within a few decades of first being able to read about all the variety of manufactures that men had devised, steam power came along and removed the difficulties that stemmed from the very limited availability of pre-steam power supplies. The new steam age was able to exploit more fully than ever before all the technical knowledge that had been accumulated, and which was presented so effectively in the French Encyclopedia. Because of the way in which it spread technical information, no less than by its enlightenment in other directions, the encyclopedia must be counted amongst the influences that made Europe what it is today.



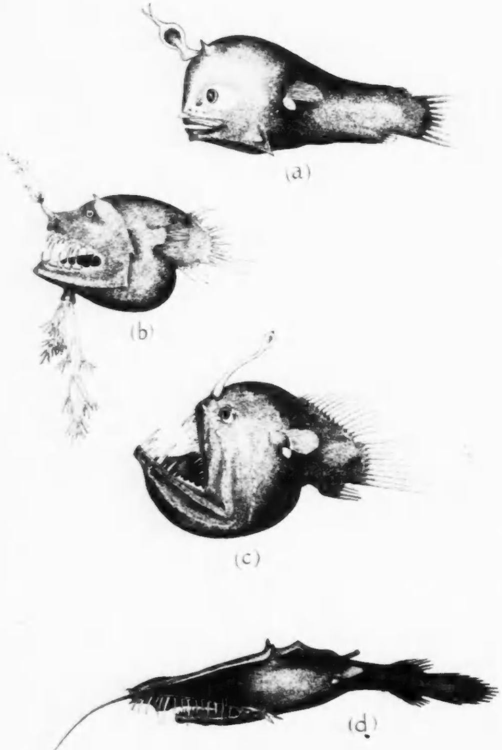



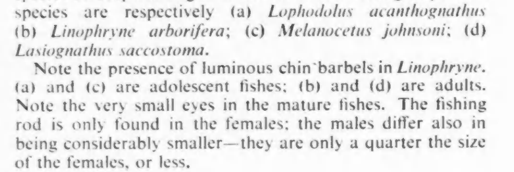

FIG. 1 (*top left*). Two different types of deep-sea fish eyes in section. The left-hand one, that of a lantern fish is the commoner. Note the characteristically large pupil and lens; these are relatively much smaller in shallow-water fishes. Compare the arrangement in the tubular-eyed fish (*Scopelarchus*) shown in the right-hand illustration.

FIG. 2 (*top right*). The detailed structure of the retina of a deep-sea fish (*Chauliodus*) as revealed in a vertical section. The pigment layer (p.l.) backs the retina; then come the long, slim, light-receptive rods (r)—note how closely packed together these cells are. N.r.c.—nuclei of rod cells; b.n.—nuclei of bipolar and amacrine cells; g.h.—nuclei of ganglion cells.

FIG. 3 (*bottom left*). The fishing rod, with its luminous bait at the end, may be stubby or very long. This illustration shows the range of form which the fishing rod takes in four species of deep-sea angler fishes of the ceratioid group. The species are respectively (a) *Lophodolus acanthognathus* (b) *Linophryne arborifera*; (c) *Melanocetus johnsoni*; (d) *Lasiognathus saccostoma*.

Note the presence of luminous chin barbels in *Linophryne*. (a) and (c) are adolescent fishes; (b) and (d) are adults. Note the very small eyes in the mature fishes. The fishing rod is only found in the females; the males differ also in being considerably smaller—they are only a quarter the size of the females, or less.

FIG. 4 (*bottom right*). Two deep-living fishes with tiny eyes. Above, the bob-tailed snipe eel (*Cyema atrum*) (length about 4½ inches); below, a whale fish, *Cetomimus* (4 inches long).



# THE LIFE OF DEEP-SEA FISHES

N. B. MARSHALL, M.A.

*A century ago almost nothing was known about the ocean depths. They were a mystery, and the prevailing view was that the abyss of the ocean was incapable of supporting life. Occasionally a strange fish or a squid with luminous organs was taken by fishermen, but only a few people realised that such animals indicated the existence of a specialised fauna adapted to life in the dark waters far below the surface of the sea. The variety and abundance of deep-sea animals was not in fact appreciated until the* Challenger *Expedition (1872–6) returned to England with its remarkable collection of species new to science. The study of deep-sea biology now began in earnest, and before the century was out it became a flourishing branch of biology. Since that time the investigation of life in the abyssal depths has gone on steadily, and animals have been brought up from ever-increasing depths. The record depth from which living organisms have been collected is 10,400 metres in the Philippine Trench; that record haul was obtained by the 1950–2 Deep-Sea Expedition of the Danes on the* Galathea.

*One of the British experts on deep-sea biology is N. B. Marshall of the Natural History Museum at South Kensington, and he has just completed a book on the subject. Entitled* Aspects of Deep Sea Biology, *this gives an excellent survey of the whole field. Of particular interest are his descriptions of deep-sea fishes and their way of life, the branch of deep-sea biology in which he specialises. Below we print some excerpts dealing with these fishes from this book.*

## THE COLOURS OF DEEP-SEA FISHES

During the *Michael Sars* Expedition in the North Atlantic in 1910, the Norwegian oceanographer Johan Hjort became convinced that there were three main layers in the ocean: (1) a surface region comprising the upper 150 metres in which transparent and blue animals and young forms of life are most prominent; (2) a region from 150 to 500 metres marked by silvery and greyish fishes; and (3) a region below 500 metres characterised by black or dark-coloured fishes and red prawns.

In actual fact, the colours of the animals of the upper and middle layers of the deep sea are not so sharply contrasted as Hjort supposed. In the region from 150 to 500 metres the lantern fishes are greyish, light brownish or silvery; the hatchet fishes have silvery, iridescent flanks; and the paralepids and *Cyclothone braueri* are pale coloured. But living in this layer and preying on the above groups are velvety black or brown fishes such as the star-eaters (Astronesthidae), and dragon-fishes (*Chauliodus*); there are also black stomiatoid fishes, which have diaphanous iridescent skins, giving off golden, copper and greenish glints. Thus dark-coloured fishes live here as well as in the deeper waters and so do a few kinds of red prawns.

But red-coloured creatures are commoner in the water masses below 500 metres; there are red cephalopods, scarlet or blood-red prawns and red nemertean worms and arrow worms. And it is particularly interesting that although reddish tints are somewhat rare in deep-sea fishes, the little brown or orange whale fishes (Cetomimidae) with bright red or orange jaws and fins, and the dark-brown coloured *Rondeletia*, with reddish-orange jaws, are mainly to be found in nets fished below a level of 500 metres.

Black or brown organisms are also conspicuous in deeply towed nets. The deep-sea angler fishes, the gulpers (*Lyomeri*) and great swallowers (*Chiasmodus*) are either jet-black or brown. But living at depths below 500 metres (down to about 2000 metres) are silvery, sleek, dagger-toothed species of *Gigantura*; rapacious fishes with forward pointing tubular eyes.

To summarize, dark-coloured creatures are by no means confined to depths below 500 metres but red-coloured species are most common in these deeper waters. Silvery, greyish and pale-coloured fishes are mostly to be found in the upper 500 metres of the deep ocean.

The biological significance of these vertical colour gradations of deep-sea animals has been much discussed. The silvery and lighter-coloured fishes of the upper reaches of the deep-sea world—and this is the blue twilight zone of the ocean—are counter shaded, the back having a darker colour than the sides and belly. Exposures with underwater photographic plates on the *Michael Sars* revealed that even at a depth of 500 metres the light was still directional: the rays were not completely diffused and scattered, meaning that shadows, even though very faint, would be cast. A fish swimming at this depth would have its back more exposed to light than its flanks and belly. When it is considered that many deep-sea fishes—and this includes predacious species—would appear to have the most sensitive eyes in the animal kingdom, the fact that many fishes have dark and not light backs may well have survival value. Is it without significance that the fishes which feed on plankton in the twilight zone—the lantern fishes, hatchet fishes and small gonostomatids, are counter-shaded, with pale or silvery sides, while their enemies such as the stomiatoid fishes are jet-black or brown? (Fig. 9). Or that the silvery fishes living below the twilight zone, *Gigantura* and *Opisthoproctus*, are not noticeably counter-shaded?

In the twilight zone red colouring is also thought to have a concealing effect. The red rays from the sun are absorbed in the surface waters, so a red creature moving below this level would appear not red but black. (Actually to deep-sea fishes it would not appear red even if red rays were present; for these fishes have none of the visual cells (cones) in the retina of the eye which are concerned with colour vision. A fish lacking cones may be presumed to be colour-blind and a red object to such a fish would presumably be perceived as some shade of grey.)

## OWL-LIKE VISION

The light that penetrates the sea surface is absorbed and scattered during its downward path; the red and ultra-violet parts of the spectrum are rapidly absorbed but the green and blue rays penetrate more deeply. Observations

made by William Beebe in the clear waters off Bermuda during his bathysphere dives revealed that at a depth of about 18 metres the red light had disappeared. At 100 metres yellow light had almost gone; and at 240 metres so had much of the green-blue part of the spectrum. Outside at the latter depth the colour of the water could only be described as "the deepest, blackest blue imaginable". Between 520 and 580 metres the water was pitch black.

But the boundary between twilight and darkness for the eyes of a human being and those of a deep-sea creature is unlikely to be at the same depth. To take a more homely example first, the nocturnal barred owl is able to pounce on its prey from a height of six feet when the intensity of light falling on the ground is between 1/70 and 1/100 of the amount necessary for human vision. In this instance the prey must have been seen; which means that the optical and light-receptive parts of the owl's eyes continue to work at light intensities well below the threshold for human eyes. The eyes of many deep-sea fishes are built on much the same lines as those of an owl (or a mouse).

For their size many deep-sea fishes have large eyes. In most of these species the bowl-shaped orbits of the skull which lodge the eyes occupy from less than a half to a quarter of the skull length. Enlargement of the eye to scale does not, however, lead to more light reaching a unit area of the retina. If the diameter of the eye-ball and pupil is doubled the light entering the eye is increased by a factor of 4 (since the area of a circle is $\pi r^2$). But doubling the size of the eye will also double the diameter of the retinal image. In other words, four times the amount of light is spread over four times the receptive area. So the light falling on a given surface of the retina will have the same intensity in all eyes with the same structural proportions, irrespective of how large they are.

If the retina is to catch more of the outer twilight, the pupil must be widened out of proportion to the increased size of the eye; and if the latter is to be optically adjusted the lens must be also enlarged. In deep-sea fishes with highly developed eyes these disproportionate enlargements have occurred; in many species the pupil diameter is from a half to three-quarters the vertical extent of the eye-ball, the relative proportions of the lens being a little less than those of the pupil.

The microscopic structure of the eyes of such deep-sea fishes reveals that the wide pupil and large spherical lens throw light on a highly sensitive retina (Fig. 1). Cones, the visual cells concerned with colour vision and sharpness of vision and which only respond to bright light, are rarely found in the retinae of deep-sea fishes. Instead, the retinae are built entirely of rods, the cells which contain visual purple (rhodopsin) and respond to very faint light (Fig. 2). Selig Hecht and his colleagues concluded that under optimal conditions one rod could be stimulated by the absorption of a single quantum of light energy, which means that theoretically the vertebrate eye has approached the maximum sensitivity for a light detector.

The rods are long and slim and are packed closely together rather like the pile of a thick carpet. Brauer found from 100,000 to 20,000,000 of these cells occupying a square millimetre of retinal surface in the various deep-sea fishes he studied. Since the rods are very long, their light-absorbing surface will be extensive and since thousands or millions of them stand on a square millimetre we may conclude that the sensitivity of the retina is relatively high.

In his stimulating book entitled *The Vertebrate Eye and its Adaptive Radiation*, Gordon Walls said that "the eyes of deep-sea fishes are probably by far the most sensitive in existence". How far down in the ocean can they see? Experiments on a species of fresh-water sunfish (*Lepomis*) showed that these fishes could see at illuminations as low as those to which human eyes respond. If the eyes of Dr. Beebe and of the sunfishes are about as sensitive to faint light, then the latter would also receive impressions in clear oceanic waters at depths down to about 550 metres. Moreover, if deep-sea fishes can see as well in blue light as *Lepomis* can in green light, then the maximum depth for vision in the Sargasso Sea would appear from knowledge of the absorption of blue light in the ocean, to be around a depth of 750 metres. And if, as seems likely, the deep-sea fishes have an extraordinary sensitivity to blue light, they may still be able to use their eyes down to at least 1000 metres. (In clear oceanic waters the intensity of blue light is reduced by about a tenth after penetrating 230 metres of depth, from which it may be calculated that even at 1000 metres there is still more than sufficient light for human vision.)

## FISHES WITH REDUCED EYES

Many of the deep-sea fishes living between depths of 1000 and 3000 metres have small or degenerate eyes. Perhaps in the upper 500 metres of this stratum (in the tropical zones) the blue rays from the sun are still to be found, but for the most part this is a pitch dark environment, lit only by the flashes and sparks from luminescent creatures. Here a small brown bob-tailed snipe eel, *Cyema atrum*, is mainly caught (Fig. 4). An individual four inches in length has eyes less than one thirty-fifth of an inch in diameter, yet each eye has a very wide pupil filled with a perfectly formed lens. The whale fishes Cetomimidae (Fig. 4), all less than six inches long, have tiny, beady eyes little more or less than one twenty-fifth of an inch in diameter. One of these fishes, *Ditropichthys storeri*, has no eyes at all.

In most female deep-sea angler fishes the eyes are small or degenerate (Fig. 3). When they are larvae and live in the well-lit surface waters of the sub-tropical and tropical ocean, their eyes, as in other larval fishes, are very well developed. But as they grow older they sink down to depths of 2000 metres or more, changing all the while into adult form. After this metamorphosis the eyes grow but little and in the largest known individuals they are quite inconspicuous.

The males of certain angler fishes have small or vestigial eyes; in others the eye is quite large and curiously developed. There is one reason why male ceratioids should have good eyes; their problem is the finding of a female in the dark. Most probably after seeing (and recognising?) the light flashes from the luminous lure of the female, they home on to the winking lure by visual means.

Many of the deep-dwelling fishes with functional eyes

which have been caught in nets below a depth of 1000 metres have probably retained their eyes 'in response to' the living light produced by themselves and other deep-sea creatures.

## FISHES WITH TUBULAR EYES

In a number of families of deep-sea fishes the eyes are shaped like a tube. They look rather like a short black cylinder, and the lens which fills the mouth of the cylinder is so large that the iris is practically eliminated.

Forwardly directed tubular eyes are found in *Gigantura* and *Winteria*, while in *Argyropelecus* and *Opisthoproctus* the eyes point directly upwards (Fig. 5).

What could be the biological significance of tubular eyes? It has been suggested that such eyes are only found in deep-sea fishes that are poor swimmers. Presumably it was supposed that tubular eyes had increased visual powers which might compensate for lack of speed. Fishes with tubular eyes have been imagined as forever peering upwards in the twilight to perceive and intercept the fall of corpses from above. Yet another suggestion is that the upward aim of tubular eyes may be associated with the predominantly downward aim of light from luminescent organs.

The tubular-eyed fishes are not confined to a narrow depth range of the ocean, and they are quite dissimilar in habit. Some species are predacious fishes able to seize and swallow prey larger than themselves; one species snaps up small fishes and crustaceans; and yet another has a tiny mouth.

The tubular eyes with their two optical axes parallel, or nearly so, meet one of the requirements for binocular vision—which is a good overlap between the visual fields of the two eyes. But as well as being binocular, the visual system is also bifocal. The accessory retina, which is closer to the lens, will be in focus for distant objects, while the main retina will come into focus for nearby objects.

Concerning the significance of binocular vision in the deep sea, Gordon Walls remarks: "If the reader will imagine trying to estimate the distance of a faint dot of light in a dark room, with one eye closed, he will appreciate the value of having bearings on such a stimulus from two angles at once."

Let us suppose that an animal has passed across the visual field of a hatchet fish. What the fish sees may be no more than a passing shadow, but the animal may have been long enough in the visual field of the fish for the latter to 'draw an optical bead' and go after it. As the fish approaches the animal the upper part of the accessory retina close behind the lens will pick up the first impression; then as the distance narrows the lower part of this retina will come into focus until finally the animal is seen as a more vivid and definite image on the main retina. For the latter to happen the fish must swim underneath the animal; and now the lateral line organs, which are particularly numerous on top of the head, and perhaps the nasal organs, combine with the eye to signal 'food'. The fish turns sharply upwards and snaps up a euphausiid shrimp. Whatever truth there may be in this reconstruction of a few seconds in the life of a hatchet fish, it would seem that the two retinas are part of a graduated focusing system. As well as indicating narrowing range, the accessory retina may detect the movements and direction of swimming of nearby animals while the fish is idling. The main retina would seem to provide a more definite and final picture before the prey is seized.

## FISHES THAT CARRY THEIR OWN LIGHTS

Special light-producing organs or photophores are found in deep-sea fishes, and also in deep-sea cephalopods and crustaceans. In any one species there may be from one to more than a dozen different kinds of photophore, the whole complex being arranged in a definite pattern. Among different species of each of these groups the photophores range from simple to highly elaborate structures, the whole forming a pattern on the body. Between different groups of fishes, cephalopods or crustaceans, there may be most striking differences in the layout and design of the photophores: between closely related species the differences in photophore pattern and structure may be slight or there may be definite but subtle variations on a particular thematic arrangement.

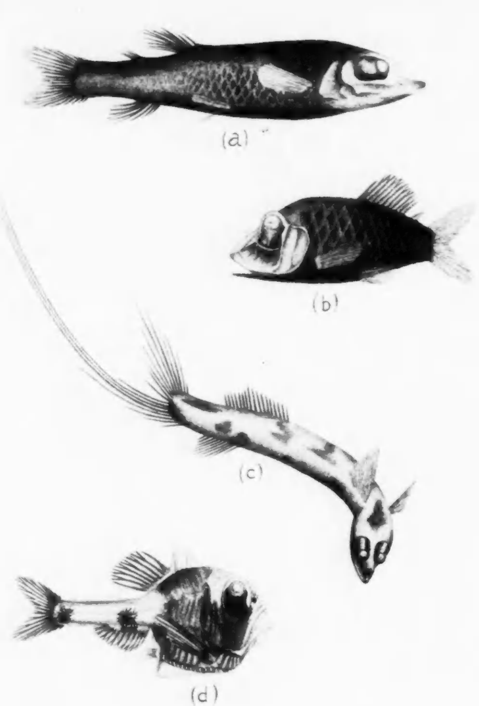
The light-producing part of the photophore consists of glandular cells or a glandular culture of luminous bacteria. Simple light organs have no more than this luminous part surrounded by a cup of black pigment cells. In more elaborate photophores the light-emitting part is enclosed by a pigment cup inside which is a layer of reflecting cells.

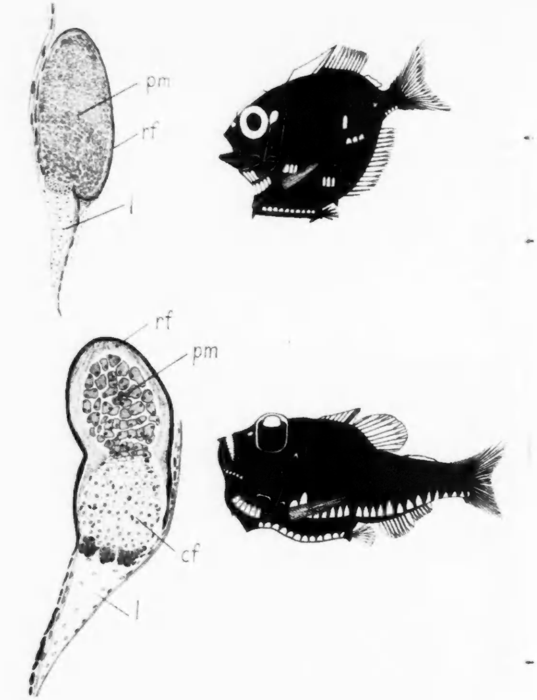
Still more complex light organs have a lens something like that of a bull's-eye lantern (Fig. 6). Some are provided with a colour filter, while others have an adjustable diaphragm of pigment cells. And in certain fishes and crustaceans, particular photophores are moved by special muscles.

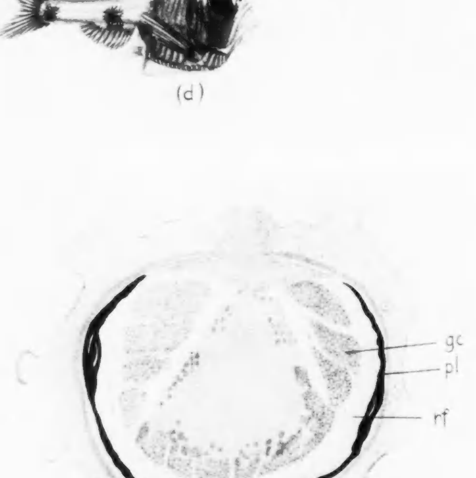
A high proportion of deep-sea fishes are luminescent; when a long series of mid-water nets are towed at many levels in deep oceanic waters the probability is that four-fifths or more of the fishes taken will bear light organs. Probably about two-thirds of the various species represented in such collections are luminous—which gives a hint of the part that luminescence must play in the lives of bathypelagic fishes.

## LIGHT AS A LURE

Fishermen in different parts of the world soon discovered the way light attracts fishes, which will swim towards a submerged lamp. The fishermen of Cezimbra, Portugal, have long been aware of living light as a lure. They take a piece of dogfish flesh and rub it on the belly of a rat-tailed fish, *Malacocephalus laevis*. Near the anus of the latter opens a gland full of luminous bacteria and from the opening discharges a viscous yellow fluid which shines with a sky-blue light. Thus the bait is smeared with a light which lasts for several hours and attracts fish to the hooks. The fishermen of the Banda Islands in the East Indies make use of the light of a surface living fish, *Photoblepharon*, for fishing at night. Just below the eye of the fish is a large gland containing luminous bacteria. The light organ is cut out and used as bait—another means of having a long-lasting luminous lure.



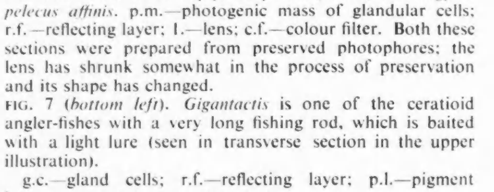




FIG. 5 (*top left*). Four kinds of tubular-eyed fishes. (a) *Winteria*, (b) *Opisthoproctus*, (c) *Gigantura*, (d) *Argyropelecus*. The approximate lengths of these fishes are respectively 5, $2\frac{1}{2}$, $3\frac{1}{2}$ and $2\frac{1}{2}$ inches. Note that in two of these fishes the eyes point forwards; in the other two genera the eyes point upwards.

FIG. 6 (*top right*). Sections through ventral photophores of the hatchet fishes *Sternoptyx diaphana* (above) and *Argyropelecus affinis*. p.m.—photogenic mass of glandular cells; r.f.—reflecting layer; l.—lens; c.f.—colour filter. Both these sections were prepared from preserved photophores; the lens has shrunk somewhat in the process of preservation and its shape has changed.

FIG. 7 (*bottom left*). *Gigantactis* is one of the ceratioid angler-fishes with a very long fishing rod, which is baited with a light lure (seen in transverse section in the upper illustration).

g.c.—gland cells; r.f.—reflecting layer; p.l.—pigment layer; s.o.—sense organ; n.—nerve.

FIG. 8 (*bottom right*). *Ceratias holboelli*, the deep-sea angler-fish with the extraordinary angling device that is described in the text. (*e*) is the female fish, with a parasitic male fish (*f*) attached.

Such lures are paralleled by the luminous gland possessed by all except two of the 80-odd species of deep-sea angler fishes belonging to the family Ceratioidea. This gland, which is found only in the females, is carried at the end of a fishing-rod (*illicium*), which is set on the snout, close to the eyes. Running from the end of the illicium to a supporting basal bone are two sets of muscles, one to raise and the other to lower the rod and bait.

The colour of the light in a number of angler-fish species has been described as purplish-orange, yellow, yellowish-green or blue-green and it seems that it is switched on and off to shine in a series of short flashes. Granules in the secretion of the luminous gland have been interpreted as luminescent bacteria. If this is so then the light may well be quenched by the closure of arteries running to the gland, for luminous bacteria require oxygen if light is to be emitted. The structure of the light gland of *Gigantactis* may be seen in Fig. 7, and drawings of the external appearance of the lure in other ceratioids in Fig. 3.

In most female angler fishes the light bait is attached to a stubby or relatively short fishing-rod, but in some genera (e.g. *Lasiognathus*, *Gigantactis* (*see* Figs. 3 and 7) and *Rhynchactis*) the rod is very long. Dr. Bertelsen has suggested that as the females slowly glide through the deep, dark oceanic waters, which are their home, the rod is extended forward and that the winking lure is twitched by the muscles running to the illicium. The approach of the prey may be detected by the lateral line organs or perhaps by touch as when a crustacean, a squid or a fish test the booty with antennae, tentacles or snout respectively. This immediately releases a series of reactions. In the species with a short rod this swings backwards, the great mouth suddenly opens and quite probably the inrush of water sucks the prey into the capacious and expanded oral cavity. But in *Gigantactis macronema* the illicium (*see* Fig. 7) is about four times the length of the body and presumably this fish, which has a slimmer, more streamlined body than most other angler fishes, must rapidly swim towards its prey.

There is an extraordinary angling device in some ceratioids. The basal bone, to which the rod is attached, is extremely movable and lies in a groove running along the head and back of the fish, to protrude backwards (when the bone is withdrawn) over the dorsal fin. The arrangement is such that a sock of skin sheaths the front and hind parts of the basal bone: also attached to the bone are muscles which move it forwards or pull it backwards. When the bone is thrust forwards the hinder skin sock is turned inside out and the forward sock, which tucked in, becomes visible.

This astonishing arrangement, which is best known in *Ceratias holboelli* (*see* Fig. 8) almost compels the following reconstruction. When the fish is angling the basal bone and rod are extended forwards so that the flashing, twitching bait is well beyond the mouth. On getting a 'touch' the retractor muscles of the basal bone move the bait closer and closer to the mouth; and if the prey is following, the rod is swung back when the basal bone comes to a stop, the large jaws open and the victim is engulfed. All this to move a light lure and attract food, but food means survival and survival may mean that the fish eventually contributes to the reproduction of its kind.

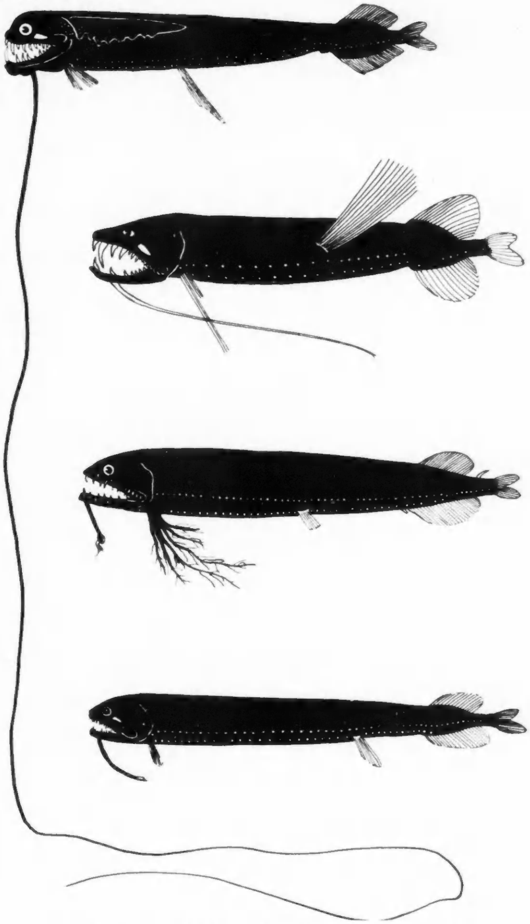


FIG. 9. Stomiatoid fishes showing the great variation in form of luminous barbels. From top to bottom: *Grammatostomias flagellibarba* (length of fish, 8½ inches); *Bathophilus longipinnis* (2 inches); *Chirostomias pliopterus* (8 inches)—note the luminous tracery on the pectoral fin; *Melanostomias spilorhynchus* (9 inches long).

August Brauer, after a close study of the luminescent organs of the fishes collected by the *Valdivia*, concluded that the luminous chin barbels of certain stomiatoid fishes were used in much the same way as the light lures of deep-sea angler fishes. When the fantastic diversity of form in these barbels is considered, some tassel-shaped, some long and whip-like with a terminal luminous organ, others carrying a luminous bulb and streamers, yet others with a bulb and an intricate luminous tracery (see Fig. 9), a strong impression remains that these organs must play an important part in the day-to-day lives of these fishes. It is, of course, possible that the barbels are means to more than one end. As they vary in form from species to species,

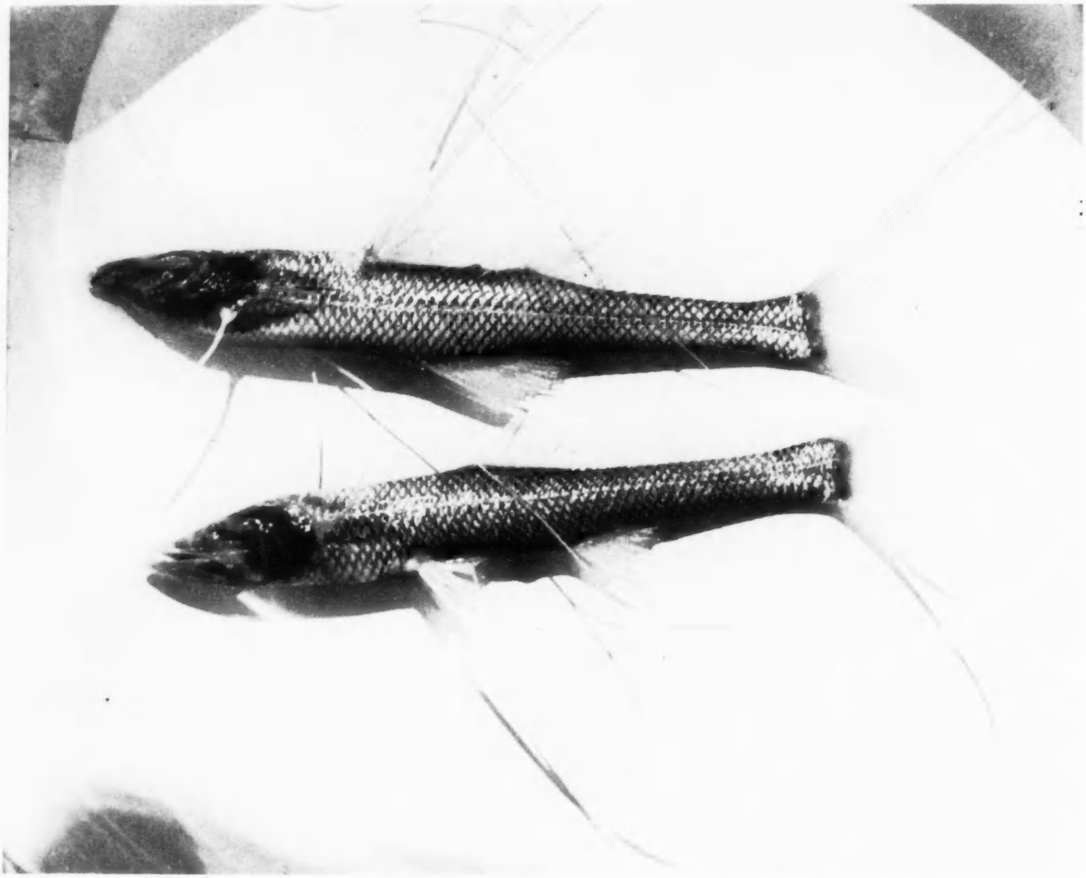


FIG. 10. These two fishes, of a species of *Bathypterois*, were caught by the Swedish *Albatross* Expedition (1947–8) at a depth of 2700 fathoms. This deep-sea fish lives on bottom-dwelling creatures such as worms. Note the long rays of the pectoral fins, which look as though they are used to probe the sea floor for food.

(*Photo by Dr. John Eriksson*)

they may be part of a luminous pattern by which the individuals of a particular species recognise one another.

May not some of the light organs which stud the body of many species of deep-sea fishes also attract prey? Probably the best indication of such a function is that *Chauliodus* and a number of related fishes not only have lights over the body but also within the mouth In *Chauliodus*, for instance, there are about 350 of these photophores, mostly arranged on the roof of the mouth and surface of the eye-ball, so when these organs are functioning the mouth will be brilliantly lit. It may well be that when the fish gulps, nearby crustaceans and small fishes dart towards the lighted gape, their entry being facilitated by the ingoing respiratory stream.

In some families of deep-sea fishes there is a large light organ behind each eye, and it is evident from observations by the scientists of the *Discovery* Investigations that these photophores may throw out a powerful beam.

Dr. E. R. Gunther thus describes the feeding activity of one silvery eel-shaped stomiatoid fish which was seen feeding at night on krill (*Euphausia*) close to the surface thus: "From a pair of luminous organs in the orbital region, the fish emitted a beam, of varying intensity, of strong blue light which shone directly forwards for a distance of about two feet. The fish had the habit of lurking at a depth of 2–6 feet below the surface, poised at an angle of about 35–40 degrees from the horizontal—this gave the beam an upward tilt: occasionally the fish swam round and with a quick action snapped at the cloud of krill above it. In its manner of lurking and of snapping prey it resembled the freshwater pike." Evidently the powerful head lights of the fish were illuminating and extending the visual field of the fish.

(*All the illustrations except Fig. 10 come from Mr. Marshall's new book and were prepared by the Author's wife.*)

# THE PREYING MANTIS

**MALCOLM BURR, D.Sc.***

There is an anecdote related of a famous old professor of entomology, who undertook to name any insect that his pupils might bring him.

Finding him difficult to circumvent even with the most unusual creatures they could find, the students made a conspiracy to build up a composite monster. With an ingenuity and patience, a touch of gum and a beetle, wasp, bluebottle, butterfly and a cockroach, they produced such a creature that no professor had ever seen outside a nightmare.

In eager anticipation of fooling their old mentor, they brought this concoction to him and asked him what kind of a bug it could be.

"Can you tell us what kind of a bug this is, Professor?" they asked.

"Easily," the old man replied unhesitatingly, "this bug is a humbug."

This story may be adapted to real life, to many creatures that actually exist, living examples that things are not always what they seem. Of all these immoral deceivers, none are worse than the mantis.

From the point of view of the inquisitive human, these creatures have an advantage over most insects, that they do not try to run away. In fact, they seem indifferent to our proximity, or even friendly. Put one on the table and it will go through its tricks and provide plenty of entertainment. Many a man on the lone trail has had cause to be thankful for the amusement they have afforded him.

There is one particular kind that outrivals its relatives in its grotesque appearance, and many a time in Spain and in the Balkans I have been entertained by the antics of these queer little insects. The kind I have in mind are the young of the eccentric genus named *Empusa*. It is a queer little monster, all spiky, with a prickly little head perched at the end of a long thin neck, legs like threads and an undersized belly tucked up like a wren's tail. It turns its head this way and that and then tucks up its arms under its chin, in that position of sanctimonious devotion that won its family its mendacious name.

For in books they are called the *praying* mantis and in most languages the native name conveys the same idea. When he was naming living creatures, Linnaeus took the Greek word for soothsayer, *mantis*, which is still used and has been accepted in our own tongue. The French often call them *réligieuses*, but the usual word is *prie-Dieu*, or in the south *prega Dios*; the Russians do the same thing when they call them *bogomol*.

But, though the mantis lives apparently in the odour of sanctity, very little observation teaches us that this sanctimonious attitude is but a cold-blooded camouflage, that beneath the assumption of religiosity the mantis conceals not a contrite heart of the *prayer*, but the cold and greedy lust of the *preyer*.

The patience of the mantis is comparable with that of the spider or chameleon, also professional trappers. For hours he will show no movement, except, perhaps, a quick turn of the head at a passing insect, in a manner that is uncannily subhuman. Then, if a fly comes near, it turns its head and cocks its goggle eyes, following every movement of its prey, as it draws ever nearer to its doom. Those eyes, usually great globes, but sometimes conical or pyramidal, are incapable of motion independently of the head; they cannot close, nor focus, nor wink, nor blink. They watch that fly as it innocently draws nearer; even the onlooker feels the strain, until, at the critical moment, an arm shoots out and in an instant the mantis, squatting on its four spidery hind legs, is holding its prey to its mouth as a squirrel holds a nut, and starts chewing. As soon as it has devoured one victim, the mantis is ready to swallow a second dinner, if only it is lucky enough to catch one. Its meal times are so unpunctual that it must make the most of its opportunities when they do present themselves, like the bushman who starves for a week and then gorges himself like a python.

So greedy are they that they do not pick and choose their prey; moreover they will eat each other as readily as any other insect. This characteristic has attracted the attention of philosophers. Krymov once published a book under the title *The Mantises in a Box*. He had seen them in India and tried to keep some in a cage to watch their antics, but he quickly found out that in a cage plural mantises soon became singular. His book was a satire upon the greed and follies of mankind, and those who are familiar with his eponyms will realise the bitterness of his irony.

Strangely in a carnivore, the jaws are neither large nor particularly powerful. Strength is concentrated in the fore-legs and it is worth considering these formidable weapons for a moment.

They consist of four long segments, hinged and horny like those of a lobster. The upper arm, so to speak, is smooth, but the forearm and hand must be taken seriously. Both have a deep and narrow groove along the underside, the two edges of which are studded with short, sharp, hard spines. The forearm is considerably broader and stouter, carrying formidable muscles and also heavily spined, while at the end there is a spur, considerably longer and stronger than the others, slightly curved. Beyond this there is a slender, weak, jointed finger. The hand closes into the forearm with the movement of a clasp knife, fitting neatly into the groove of the forearm. When that is shut and those double rows of spines are engaged, the clutch is final.

This end spur is also a powerful weapon. Often, when holding a big living mantis in my hand I have been startled into letting it go by the sudden pain, as it deliberately dug this spine into my flesh.

Mantises range in size from less than an inch to monsters that are among the biggest of insects. Within the family

* Dr. Malcolm Burr, who died in Turkey this summer at the age of 76, began his career as a professional geologist (he was associated with early development of the Kent coalfield), and then made his name as an entomologist. This article was written shortly before his death.

# DEATH OF A COCKROACH . . .

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*These pictures of a mantis devouring its prey were taken in the Bronx Zoo.*



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there is an endless diversity of form and colouring. They are among the most curious and fascinating of all insects.

The commonest sorts are merely green, with the veining of the forewings resembling that of a leaf, so that they harmonise with the foliage among which they sit. Brown specimens occur, especially late in the season, thus adapted to the vegetation that has lost its greenness.

Some carry the resemblance to dried leaves to an unbelievable degree. In one African genus the pigment is absent through the greater part of the wings, making them transparent, with a brown spot here and there along the edge: the limbs, neck and tiny head look like dried twigs. I have caught one of these in Angola by sheer chance, for it was virtually invisible and I could scarcely realise that it was a living insect that I was holding in my hand and not a half-rotten leaf.

Another kind that I discovered in the same country fairly took my breath away. It was a small insect, hardly more than an inch in length. The general colour was greenish-grey: the body, head and limbs were furnished with extensions of the membrane in the form of little lobes, which were black underneath. These tended to curl slightly upwards and so gave the appearance of a grey and black mottled pattern. In fact, it looked exactly like a piece of lichen. When I placed it upon a piece of lichen, it simply vanished then and there. It was positively uncanny. I placed it upon a lichen-covered stick a few inches long and showed it to my comrade, asking him to 'spot the lady'. He refused to believe me when I told him that on that little bit of twig there was sitting a living insect, and by no means a small one. On the lichen it refused to move, as though knowing that its concealment was most perfect when it was motionless. But when I put it down on a patch of white sand, it scuttled about vivaciously, as though aware of the danger to which it was exposed by its unaccustomed conspicuousness, hunting for a piece of lichen on which to sit down.

Others again there are that look like flowers. There are several kinds of flower-mimics. Walking one day through the scrubby forest in the highlands of Angola, I noticed a pretty little mauve pea, gently swaying at the end of a long stalk. There were one or two of them, so I went to pick one. To my astonishment, it dropped off and ran away. It was not a flower at all, but a little mauve mantis, that had the habit of sitting at the end of a long stalk, dancing gently as though swaying in the breeze.

This swaying habit has not gone unrecorded; there is one record of a mantis in Egypt that danced to the tune of the restaurant band.

Their inveterate habit of camouflage deprives them normally of externally vivid colour pattern, but there is one place where they are apt to keep concealed spots of colour. Normally a mantis keeps its wings and the elytra that cover them folded fanwise along the back. The wings themselves are seldom seen, being almost always concealed by the overlying elytra, which are generally of a monochrome pattern. But in many cases these hidden wings are decorated with brilliant eye spots, often very beautiful.

In central Africa I found one lean and lanky mantis, and this species looked almost more like a spider than an insect. The wings were reduced to tiny flaps and dingy in colour. In specimens of this kind of mantis the secret coloration is hidden in a most unexpected way. When I opened their abdomens to dry them for preservation, I found that the insides, instead of yellowish or pinkish as usual, were of a brilliant turquoise blue. I can hardly believe that they can make any use of this for defence, although it is true some crickets squirt their blood out to frighten people away. I do not believe there is any *utility* about this surprising colour scheme, but rather that it is a physiological by-product, like the black spots on the wings of white butterflies, which are a deposit of their excess of urea.

There is one genus of mantis that has a type of coloration unusual in the insect world, namely a glittering Prussian blue. It is probable that this colour is what scientific people call 'aposematic' and ordinary naturalists 'warning colours', an outward and visible sign of an inward and invisible nastiness. The net effect is to discourage birds or lizards from eating them. If they are nasty to the taste, the insects rely on the principle of 'once bitten—twice shy'.

Though so well concealed against potential external enemies, these insects are very liable to attack by internal foes. In collecting it is necessary to empty the abdomens of the rather portly females in order to preserve them. In doing so I found in a considerable proportion, the abdomen was filled with the endless coils of a long, slender intestinal worm called *Gordius*, which makes a speciality of living inside insects. The mantis had practically no internal organs left and must have shortly succumbed to starvation without leaving progeny.

It is unfortunate that there are no wild mantises in our islands, for they would be useful in keeping down the number of insect pests. Their absence from Britain is not primarily due to any defect of our climate, for in our southern counties there flourish many kinds of insects of southern origin. The explanation is to be found in the history of our islands.

When the British Isles were finally separated from the Continent some seven or eight thousand years ago, a considerable contingent of insects, and also of some vertebrates (such as the smooth snake and the agile lizard), had reached our shores as they worked their way northwards to recover territory after the receding ice. The mantises, however, which are of African origin, were just too late. They reached the centre of France, perhaps even the north, but could not reach our shores. In fact, they 'missed the bus'.

There is no reason, so far as I can see, that they should not be introduced and naturalised. It is hard to believe that they could do any harm, as do so many foreign intruders, because they are purely carnivorous and the good they could do in helping to keep down flies and other pests would be considerable. I suggest that those who have the opportunity should send home, preferably selecting the common European *Mantis religiosa*, those papery clusters of eggs that are far from rare in the south, or even centre of Europe, often attached to a brick, a flat stone or a twig. These could be reared, perhaps at first in big cages or in a glasshouse and later, when they are strong enough to take their chance in the world, be released in a garden.

# RESEARCH IN THE ARCTIC

MAURICE GOLDSMITH

The Arctic is the 'Far West' of the mid-20th century. It is a vast area, unknown and undeveloped, but rich in natural resources. With the coming of the aeroplane, its strategic importance in relation to the two great land—and political—masses of North America and Soviet Asia has grown.

Soviet Arctic research is flourishing. Professor V. Frolow, director of the Arctic Scientific Research Institute, recently said in *Izvestia*—reported a Special Correspondent of *The Times* on November 1, 1954—that the Arctic has always played an outstanding role in the economic and political life of Russia. The country's geographical position, with its main façade towards the Arctic Ocean, had determined the profound interest in it which the Russian people had always shown.

The counterpart, in a sense to the Soviet Institute, is the Arctic Institute of North America. When, a few weeks ago, I was in Canada, I went to the Institute's Montreal office to see Dr. Svenn Orvig, its director. (There are two other offices, with their own directors, in Washington and in New York.) Dr. Orvig took over in July this year from Mr. P. D. Baird, who resigned to join the staff of the Department of Geography at Aberdeen University.

The southern boundary of the Arctic zone corresponds roughly to the tree line. Anything north of a line which indicates a mean temperature of 10°C (50°F) for the warmest month is regarded as lying in the Arctic zone. This includes most of Alaska and Greenland and a large part of Canada.

For Dr. Orvig, this region presents an unexcelled opportunity "to add significant data to man's knowledge of his environment and himself". As he has put it, "This area constitutes a huge laboratory, a natural experimental set-up not to be matched in temperate zones. The extremes of temperature, the perennially frozen ground, the alternating periods of constant daylight and darkness, the remnants of glaciation, the Aurora, the biological adaptivity of plants and animals, the profusion of life in the Arctic seas, the indigenous peoples—all invite studies in the natural, biological and social sciences."

The Arctic Institute of North America was founded in 1945 to advance the scientific study of the North American Arctic and Subarctic. Many agencies, governmental and private, are concerned with particular aspects of northern research, but the Arctic Institute is the only organisation devoted to furthering fundamental knowledge of Arctic North America as a whole. It was understood, when founded, that many of the problems are common to Alaska, northern Canada and Greenland, and economy of effort can be achieved by treating the region as a whole.

The major part of the Institute's effort is devoted to the conduct of field research. By the close of the current (1954) field season it will have sponsored, in whole or in part, one hundred and sixty separate projects. They span the North from Alaska to Greenland and range from small-scale, highly specialised studies to large expeditions concerned with many aspects of science and continuing their investigations over a period of years.

The Institute has also compiled an Arctic Bibliography, a monumental work, the first four volumes of which have been published by the U.S. Government Printing Office. Associate members and Fellows of the Arctic Institute include interested laymen as well as the outstanding polar workers in North America. Through its quarterly journal, *Arctic*, the Institute disseminates technical and general information.

The Institute is affiliated to the National Academy of Sciences and the National Research Council of the United States.

The facilities of the Institute include a trained staff, research library and map collections, and scientific equipment for loan to field parties.

In addition, the Institute has recently assumed responsibility for the scientific programme of the Arctic Research Laboratory of the Office of Naval Research at Point Barrow, Alaska.

Support for the Institute came originally from the National Research Councils of the United States and Canada, and from the Carnegie Corporation of New York. Since then it has received financial assistance from the Rockefeller Fund, the Sir Frederick Banting Fund and from many corporations and individuals.

The bulk of its research programme has been supported by agencies of the United States and Canadian Governments, for the most part through contractual arrangements for individual research projects. The Institute is, however, now presenting a broad appeal to industry for financial support.

The Institute is also courting the scientific worker, Dr. Orvig told me. Grants-in-aid for research projects are awarded yearly. "Any who have such projects in mind, or who wish to inquire about ways in which their scientific interests may find expression within the Institute's programme are urged to get in touch with us. The Institute will welcome word from any who are interested in helping to further the great task it has undertaken—to accelerate and expand the scientific study of the North that we may more fully and speedily realize its economic, strategic and scientific potentialities," said Dr. Orvig.

The Research Committee of the Institute has just completed a review of the present status of Arctic research. Specialists throughout North America were asked for the most pressing problems on which research should be focused. It was felt that the time had come to draft a long-range research programme, something purposive to replace the initial, fruitful but haphazard, exploration period. A volume devoted to these long-range research needs is now in preparation, and is expected to serve as a guide for the future study of the entire Northland.

What are the needed lines of research? They can be classified most conveniently by considering the major

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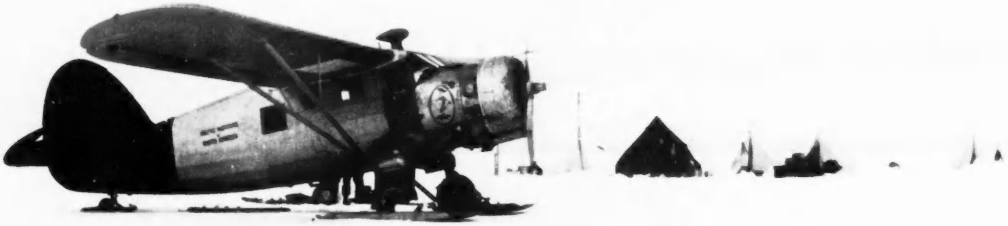


The modern scientific expedition has to meet all the age-old problems of transportation over snow and ice. One effective aid to such expeditions is the ski-equipped plane, here seen bringing supplies to a scientific unit on Baffin Island. (*Photographs by Dr. Svenn Orvig*)

branches of science, one by one, and where there are gaps in our knowledge that require a major research effort to fill them.

## 1. GEOLOGY AND GEOMORPHOLOGY

The one generality relative to the status of northern research in this field is the deficient state of such research. The following segments of research are mentioned because of their special importance.

*Geological Mapping.* Part of this task is being taken care of by Government, but there is ample room and need for the participation of other groups. For instance, the Arctic Institute can focus interest on local studies and mapping, and research on special geological problems.

*Geological Processes.* This knowledge is absolutely essential to northern agriculture, engineering, construction of all types, transportation, and such public health problems as water supply and sewage disposal.

Among the fields on which more data are needed are:

*Permafrost.* Much more remains to be done by both Government and private groups before permafrost and various ways of handling it are adequately understood for the many purposes of northern development. The problem of permafrost affects almost every enterprise contemplated in the North.

*Glaciology.* Experience has shown that Government participation in glaciology is likely to be insufficient for satisfactory progress. Results in this field would have an immense and immediate application, for glaciology touches upon such fields as climatology and meteorology, as well as basic geologic processes.

*Stratigraphy.* Over much of Arctic North America knowledge in the fields of stratigraphy and structure is so fragmentary and superficial as to be useful only in the broadest fashion. Detailed knowledge is needed both for local understanding in relation to oil and other mineral deposits, and for helping to fill the gaps in current knowledge of the major stratigraphic and structural patterns.

*Ground Water Geology.* With the coming of larger settlements and military establishments to Arctic regions, the problems of water supply and sewage disposal have assumed critical proportions. Already some of the larger communities are facing serious water problems that may be solved in part by the development of underground water supplies. The principles that control the occurrence and movement of underground water in permafrost areas are not well understood and call for early investigation.

*Engineering Geology.* Special problems arise when foundations have to be laid for large structures and for such works as highways, dams and airfields built on permanently frozen ground. Low winter temperatures also necessitate the giving of special attention to construction materials of high insulating value.

## 2. GEOPHYSICS

The extent and nature of some geophysical problems require governmental operation for establishment of basic data and their subsequent analysis.

*Ionospheric Studies* and observations of the Aurora are important in the determination of radio-wave propagation in the Arctic, and they would yield information which would be applicable to the maintenance and improvement of radio communication, which is under some conditions the only means of communication over this vast region.

*Seismic Observations* would be valuable, as they provide an effective means of investigating the earth's interior. (The transmission of different types of seismic waves over varying paths furnishes significant information regarding the structural and physical state of the interior.)

## 3. OCEANOGRAPHY

The science of oceanography combines wide phases of geophysics, geochemistry, biology and meteorology. For the Arctic it concerns an icy ocean basin, open seas, bays and inland waters. Geographically, the area covered by these waters (the central basin equals that of the U.S.A.) is greater than the land area. In much of the area the collection of oceanographic data is an expensive business as it cannot be done without ice-breakers and other deep-water vessels; elsewhere much useful work can be done from smaller vessels, aeroplanes and shore stations.

## 4. BOTANY

The solution of many botanical problems in the Arctic and Subarctic zones will yield valuable and practically useful information for many purposes, civilian and military. The significance of these problems in the extensive use of Arctic and Subarctic lands by human populations lies first in the evidence they can give of the major geographic patterns or natural areas in the boreal regions. It is upon these major patterns that the outlines of use must eventually be based. A second system of application is a refinement of the first. It involves the use of the natural vegetation in its relationship to local environments to indicate the cultural capabilities of the land. A third application is of large military significance. It involves the use of vegetation as an indicator of the 'kind of ground'. All of these applications of botanical science to the intelligent use of the land depend upon botanical knowledge in all its various aspects. The field for investigation is enormous, for botanical science is still in its infancy for most Arctic and Subarctic regions.

## 5. ZOOLOGY

The distribution of Arctic animals is very poorly known; the special characteristics of these animals are even less known. The Arctic environment exacts extremes of adaptation of great interest and importance to man in his efforts to live in the North. One of the most important features of animal populations in the North is extreme variation in numbers at regular intervals. These cycles have been studied, but there is abundant room for further research. In recent years it has become known that the important human diseases, rabies and trichinosis, are endemic in Arctic animals, but their ecology remains to be worked out in detail.

The Arctic seas are rich in animal life, which has, however, received comparatively little scientific attention.

## 6. MARINE BIOLOGY

Two of the pressing research needs in northern marine biology are:

(*a*) The elucidation of the factors governing and limiting the production of living matter in northern seas. Why are Subarctic waters always more productive than regions of pure Arctic water originating in the Polar Sea? This is a fundamental biological question; upon its solution depends our real understanding of the biology of those fish and mammals of more immediate usefulness to man.

(*b*) The stocktaking of marine food resources, and the estimation of the 'take' that each species in each locality can stand without depletion. This requires the study of growth rates, rates of reproduction and so on in a number of species such as ringed and bearded seals, walrus, beluga and narwhal, Greenland shark and Arctic char.

### 7. ANTHROPOLOGY AND HUMAN ECOLOGY

The Arctic is the most extreme and difficult environment ever faced by man. Sustained human life in low temperature areas poses problems of a kind encountered nowhere else in the world. Nevertheless, by a series of ingenious adaptations primitive tribes, especially the Eskimo, have been able to solve the problem of Arctic living. As increasing numbers of Americans and Canadians move into the Far North there is urgent need for scientific knowledge of the physical, biological and environmental factors affecting living conditions there.

These are some of the basic problems towards which research should be directed. The physiological effects of extreme cold on native and white populations, varying susceptibility of Eskimos and whites to imported and endemic diseases, relation of diet to health and disease; the physiological and nutritional effects of a high-fat, all-meat diet versus a balanced diet on (*a*) Eskimos living under primitive conditions, (*b*) those who supplement their diet with some white food, and (*c*) Eskimos and whites depending entirely on imported foods; possible physiological differences between Eskimos and whites; social and psychological factors affecting adaptability of native peoples to new living conditions and new forms of employment; cultural, physical and linguistic relationships between inland and coastal Eskimo groups.

There is plenty of scope for archaeological studies to help fill the gaps in our knowledge of Early Man on this continent, and of the development of Eskimo and Indian patterns of culture in the Far North.

### 8. METEOROLOGY AND CLIMATOLOGY

Through the government meteorological programme in both Alaska and Canada valuable data of great interest to meteorologists is constantly being assembled. Investigations into weather and climate will of course be of considerable importance to shipping interests considering the extension of the range of their operations into the Arctic.

The kind of details that need to be collected include such things as the annual accretion of both sea and freshwater ice correlated to freezing degree days, and the date of initial freeze-up.

It has been proposed that a solar heat pump could solve some specific heating problems in the Arctic; in this connexion it would be necessary to study how the amount of sun falling on one spot is affected by variations in the quantity of snow that is blowing about.

It is planned to measure the temperature gradient in the snow; the temperature measurements will be made at three-inch intervals in the top 1 to 2 feet of soil, at least once a week and in a sufficient number of sites. These data will assist in determining whether it is really profitable to compact snow surfaces in the Arctic for landing strips; the present view is that it is almost impossible to compact snow crystals under conditions of extreme cold without the use of a great deal of heat and/or the addition of chemicals which produce crystalline change. On the other hand, however, snow might be successfully compacted by other methods not yet tried. The policy of the Arctic Operations Project of the U.S. Weather Bureau is to remove the snow from the landing strips; this has been done for the past several years, but the scientists of the Arctic Operations Project are looking for other ways round this particular problem.

## CERN: THE EUROPEAN CENTRE FOR NUCLEAR RESEARCH

CERN, the European nuclear research laboratory which is being set up in Geneva, has given some details of its plans for research equipment. A giant synchro-cyclotron is to be erected, and the 2000-ton magnet required for this should be ready in a year's time; its installation should be completed inside eighteen months. It is anticipated that the machine will be working in 3–4 years. CERN's proto-synchrotron should be ready within 6 years. Prof. Bloch, who won the Nobel Prize for Physics in 1952, has been appointed director of CERN. A native of Zürich, where he was born in 1905, he spent most of his years after 1933 (he was working in Leipzig when Hitler came to power) in the U.S.A.

In America he started on his neutron work, which led in 1936 to the publication of his key paper on the possibility of verifying the existence of a magnetic moment of the free neutron. Turning to experimental work Bloch, in collaboration with Alvarez, achieved the first measurement of the magnetic moment of the neutron. This was done in 1939 with the use of the cyclotron at Berkeley.

War research interrupted his fundamental investigations, but as soon as he was able to get back to Stanford in 1945 he started developing methods of studying the magnetic moments of nuclei. Success came in 1946 when he published his theory and, together with a number of collaborators, the experimental technique of measuring nuclear magnetic moments. It was for this discovery, which he called 'nuclear induction', that Bloch was awarded the Nobel Prize.

The governing council of CERN is presided over by Prof. W. Heisenberg of Germany. The British members of the council are Sir John Cockcroft and Prof. P. M. S. Blackett.

# FAR AND NEAR

### Night Sky in December

*The Moon.*—Full moon occurs on Dec. 10d 00h 56m U.T., and new moon on Dec. 25d 07h 33m. The following conjunctions with the moon take place:

| December | | | |
|---|---|---|---|
| 2d 16h | Mars in conjunction with the moon | Mars | 6° S. |
| 12d 22h | Jupiter ,, | Jupiter | 3° N. |
| 21d 15h | Saturn ,, | Saturn | 6° N. |
| 21d 20h | Venus ,, | Venus | 7° N. |
| 31d 12h | Mars ,, | Mars | 6° S. |

In addition to these conjunctions with the moon, Venus is in conjunction with Saturn on Dec. 16d 00h, Venus 0·7° N.

*The Planets.*—Mercury is a morning star, rising at 6h 30m on Dec. 1, but as this is only 1h 20m before sunrise it will not be visible for long; as it draws closer to the sun during the month it will not be a conspicuous object at any time in December. Venus, a morning star, rises at 5h 40m, 4h 40m, and 4h 20m, on Dec. 1, 15, and 31, respectively; its stellar magnitude varies from −4·0 to −4·3, and the visible portion of its illuminated disk from 0·080 to 0·340. During the month its distance from the earth varies from 28 to 45 millions of miles, and in spite of the increasing distance the planet becomes brighter because of the increase in the visible portion of its illuminated disk. Mars is an evening star, setting about 22h 15m during the month. Its stellar magnitude varies from 0·5 to 0·8 and the visible portion of its illuminated disk from 0·862 to 0·881. The increase in the visible portion of the illuminated disk does not compensate for the increased distance of Mars from the Earth, which is 112 million miles at the beginning of December and 132 million miles on Dec. 31. Careful observation will show that Mars is a little N. of $\iota$ Aquarii early in December, and towards the end of the month it has moved close to the constellation Pisces N.E. of Aquarius. Jupiter, an evening star, rises at 19h 40m, 18h 40m, and 17h 25m, on Dec. 1, 15, and 31, respectively. Its stellar magnitude, which is 2·1 during most of the month, is −2·2 towards the end of December, the slight increase in brightness being due to the decrease in the planet's distance from the earth, from 423 to 400 millions of miles. The slow westward movement in Cancer can be detected by careful observation. Saturn, a morning star, rises at 5h 30m, 4h 45m, and 3h 50m on Dec. 1, 15, and 31, respectively. Its very slow eastward movement from $\alpha$ Librae towards $\nu$ Librae (the latter star is very faint and just visible to the naked eye) can be detected by careful observation.

On Dec. 25 there will be an annular eclipse of the sun, but it will be invisible at Greenwich. The path of this eclipse which, not being total, will have little scientific value, begins on Dec. 25d 04h, 34·8m G.M.T., and will be visible in South Africa and the southern Indian Ocean. A small partial eclipse will be seen at sunset in Australia.

The Geminid meteors attain their maximum on Dec. 11–13, but owing to strong moonlight at the time it will not be possible to see the shower under favourable conditions. It is remarkable that these meteors move round the sun in a small orbit comparable with the orbits of some of the minor planets. There are other meteor streams that pursue similar small orbits, though most meteor showers have fairly large orbits, resembling those of comets. Winter Solstice occurs on Dec. 22d 09h.

### 1954 Nobel Prize for Physics and Chemistry

The 1954 Nobel Prize for physics has been shared between Prof. Max Born and Prof. Walther Bothe of the Max Planck Institute in Heidelberg. The prize for Chemistry goes to Dr. Linus Pauling of the U.S.A.

Prof. Born is 72. He was born in Germany in December 1882. The first professorship he held was in Berlin, and he later occupied professorial chairs at Frankfurt and Göttingen. The last-mentioned post he held from 1921 until 1933, when he was forced to leave Germany. He had by then made many contributions to the advance of theoretical physics. After his arrival in England he continued his work at Cambridge, where he was appointed Stokes Lecturer in Applied Mathematics. In 1936 he moved to Edinburgh to become Tait Professor of Natural Philosophy. His numerous books include one volume on Einstein's theory of relativity, and works on atomic dynamics and mechanics. His latest book was published in 1949, and was entitled *A General Kinetic Theory of Liquids*.

* * *

Prof. Bothe has done important work in the cosmic ray field. With H. Becker he made an outstanding contribution to a sequence of research work that culminated in Chadwick's discovery of the neutron in 1932.

* * *

Dr. Pauling was awarded his Nobel Prize for "his works on the nature of chemical bonds, especially as applied to the structure of complicated substances". In his lecture to the American Chemical Society in June 1946, on the occasion when he was presented with the Willard Gibbs Medal, he told how his interest in the nature of the chemical bond was aroused by reading the papers of Lewis and Irving Langmuir. That was 1919, and since that time most of the methods which form the basis of modern structural chemistry have been developed—including molecular spectroscopy, the determination of the configuration of gas molecules by the diffraction of electrons, the measurement of the electric dipole moments of molecules, the measurement of magnetic moments and of diamagnetic susceptibilities, the interpretation of heat capacity, entropy, and other thermodynamic quantities, and the application of theory, especially quantum mechanics.

Pauling has made many contributions to this field. His researches started soon after his graduation in 1922; he had been studying chemical engineering at Oregon State College. After holding a teaching fellowship for three years at the California Institute of Technology, he went abroad, to study in succession with Prof. Arnold Sommerfield in Munich, Niels Bohr in Copenhagen, and Erwin Schroedinger in Zurich. He returned to 'Caltech' in 1927, where he became a full professor in 1931, and head of the division of chemistry and chemical engineering in 1937.

His researches have included studies on the determination of the structure of crystals and molecules, the application of quantum mechanics to chemistry, the rotation of molecules in crystals, the sizes of ions, the theory of stability of complex crystals, the chemical bond, line spectra and immuno-chemistry. In 1940 he published the first of a series of papers advancing a theory of the structure and formation of antibodies, the agents developed by the body to fight disease organisms, which has provided a basis for extensive investigation of the activity of serums.

His writings include the famous book entitled *The Nature of the Chemical Bond*; he was co-author of *The Structure of Line Spectra* and *Introduction to Quantum Mechanics with Application to Chemistry*. His work has been recognised by the Royal Society, which awarded him the Davy Medal in 1947.

### A British Hydrogen Bomb Test?

In the *Daily Express* for Nov. 15, Chapman Pincher published a story to the effect that the British Government is seeking a remote island site for a hydrogen bomb experiment. The report said that our defence chiefs may seek permission to use the U.S. testing ground at Eniwetok Atoll in the Pacific, and added that, if this was refused, some other Pacific island well clear of shipping routes will probably be selected.

### The Effects of Television

The Nuffield Foundation is sponsoring an investigation into the effects of television on children and young people. It was felt that this could best be done by an independent body, but the British Broadcasting Corporation has promised to co-operate to the full. The team of investigators will be led by Dr. Hilde Himmelweit, Reader in Social Psychology, London School of Economics, who will be guided by a Steering Committee under

Sir Hector Hetherington of Glasgow University.

Members of this Committee are: Mr. J. G. Dent, Headmaster, Fulwood County Secondary School, Fulwood, Lancs; Prof. G. C. Drew, Dept. of Psychology, Bristol University; Mr. L. Farrer-Brown, Director, Nuffield Foundation; Prof. M. G. Kendall, Dept. of Statistics, London School of Economics; Prof. A. R. Knight, Prof. of Psychology, Aberdeen University; Miss Janet Morrell, Loughton High School for Girls; Prof. P. E. Vernon, Dept. of Educational Psychology, Institute of Education, London University; Prof. J. Z. Young, Dept. of Anatomy and Embryology, University College, London; Mr. R. Silvey, Head of Audience Research, B.B.C. (*observer*); Mr. J. E. Morpurgo, Assistant Secretary, Nuffield Foundation (*secretary*).

**Royal Society Medallists**

The following awards of medals have been made by the President and the Council of the Royal Society:

*The Copley Medal* to Sir Edmund Whittaker, F.R.S., for his contributions to both pure and applied mathematics and to theoretical physics.

*The Rumford Medal* to Dr. C. R. Burch, F.R.S., for his contributions to the technique for the production of high vacua and to the development of the reflecting microscope.

*The Davy Medal* to Dr. J. W. Cook, F.R.S., for his fundamental investigations in organic chemistry.

*The Darwin Medal* to Dr. E. B. Ford, F.R.S., for his contributions to the genetical theory of evolution by natural selection, particularly in natural populations.

*The Hughes Medal* to Mr. M. Ryle, F.R.S., for his researches in radio astronomy.

**Royal Society's Research Appointments**

The Council of the Royal Society has made the following research appointments:

The Alan Johnston Lawrence and Moseley Research Fellowship to Dr. D. S. Robinson, of the Sir William Dunn School of Pathology, Oxford University, for work on the biochemistry of lipid distribution and transport in plasma.

Stothert Research Fellowships to Dr. B. L. Ginsborg, of University College, London, for work on neuromuscular transmission; and Miss D. Salmony, B.Sc., of the Courtauld Institute of Biochemistry, London, for work on the effects of sex hormones on cell metabolism.

The John Murray Travelling Studentship in Oceanography and Limnology for 1954 to P. Hughes, B.Sc., of Liverpool University, for study of wind drifts in the oceans.

Awards under the Royal Society and Nuffield Foundation Commonwealth Bursaries Scheme are announced as follows:

Prof. R. H. Common, chairman of the Dept. of Agricultural Chemistry, McGill University, to study avian biochemistry, principally at Reading.

Dr. D. E. Coombe, fellow of Christ's College and university demonstrator in Botany at Cambridge University, who is to visit W. Africa during 1955 to study tropical forest vegetation.

Dr. J. Crossland, physiology lecturer, St. Andrews, who goes to Montreal to collaborate with Dr. K. A. C. Elliott in studies on the behaviour of acetylcholine in the brain.

Mr. J. R. Howes, lecturer in Animal Husbandry, Imperial College of Tropical Agriculture, Trinidad, who is studying problems and methods of research in African animal production, at Pretoria and in Kenya.

Dr. A. P. Subramaniam, of the Geological Survey of India, who will work with Prof. C. E. Tilley at Cambridge on a petrographic study of rocks from the type Charnockite area around Madras.

Mrs. Patricia M. Thomas, of Adelaide, to enable her to carry out heminthological studies at Macdonald College, Canada.

These are the first awards under the scheme which was instituted in 1953 to provide facilities for increasing the efficiency of scientists of proven ability by enabling them to pursue research, learn techniques or follow other forms of study in natural science in countries other than their own in the Commonwealth where the physical or personal environment, or both, are peculiarly favourable.

**British Interplanetary Society Comes of Age**

On October 16 the British Interplanetary Society celebrated its twenty-first anniversary with a meeting at Caxton Hall, London, and a dinner at the Waldorf.

The lecturers at the meeting included: Dr. L. R. Shepherd, P. Moore, J. Humphries, A. C. Clarke, and K. W. Gatland. Guests of honour at the dinner were P. E. Cleator, the Founder of the Society, and Professor H. Oberth, a distinguished pioneer of astronautics and author of *Wege für Raumschiffahrt* (Way To The Stars), published in 1929.

**Smog Damage to Plants**

A new method of identifying smog damage to vegetation has been developed by Stanford Research Institute plant physiologists. The Institute's Air Research Laboratories are now using ultraviolet light to produce a characteristic pale blue fluorescence of markings on plants damaged by smog. Research has definitely associated fluorescence with leaf damage.

First hint of the relationship between fluorescence and smog damage came following a smog attack observed in 1953. Dr. Nielsen and Dr. Benedict noted that so-called typical smog markings on certain weeds (*Chenopodium murale* and *Malva parviflora*) fluoresced pale blue when irradiated by ultraviolet light. Unmarked portions of the leaves did not show this fluorescence.

Following observations at the Menlo Park laboratories, Dr. Benedict gathered samples of vegetation in the Los Angeles area and checked further. These leaves also showed the fluorescence. The markings appeared blue.

Under visible light their colour showed little relationship to the fluorescent colour. Silver, tan and brown areas all fluoresced pale blue. As the leaves dried the intensity of the fluorescence increased markedly.

As a further test, plants of spinach, romaine, endive, sugar beet and some weeds were fumigated with mixtures of ozone and hexene, ozone and gasoline vapours for sufficient time to produce leaf markings. These fluoresced like those produced by smog and further studies are being made in this direction. The reason for the fluorescence has not been determined.

**'Pyrex' Test Tubes with Screw Tops**

The first 'screw-top' heat-resisting glass test tubes ever made in Britain are being produced by Jobling & Co. Ltd., in Pyrex glass. The firm is fulfilling a top-priority order from medical research workers whose aim is to produce, with the aid of these tubes, a polio vaccine.

These test tubes are 105 mm. in length, with a diameter of 16 mm. Each has a 'screw-top' on to which a metal or plastic cap may be fitted.

**Creating New Plants with Colchicine**

The artificial induction of polyploidy in crop plants by use of the drug called *colchicine* is being tried throughout the world, and the technique has several notable successes to its credit. When application of the drug results in a doubling of the number of chromosomes within the cell nucleus, the gross effect is usually an increase in the size of the mature plant, which commonly produces giant fruits.

A good example is the colchicine-derived decaploid strawberry (No. 4206), with 70 chromosomes, synthesised by the U.S. Department of Agriculture. One of the centres for such research in America is the U.S.D.A.'s Plant Industry Station.

At this station work is being done on a number of plants, including grapes. The colchicine technique is of special interest since it offers a way round the difficulty of getting a fertile cross between two kinds of grape. The South-Eastern muscadine grape is a diploid with 40 chromosomes. It does not cross readily with the Northern bunch grape, a 38-chromosome diploid, and the few hybrids which have been obtained have proved sterile. Yet bunch grapes need the vigour and disease resistance of the muscadines. The muscadines, in turn, need the large cluster form of the bunch grapes.

Experience with other plants suggested the possibility of making a fertile hybrid by doubling the chromosomes of both of these diploid grapes before attempting the cross. So plants of ten Northern selections and varieties were treated with colchicine. Tetraploids developed among all ten. Several Southern-type grape plants are

now in process of polyploidisation so that the stage is now set for new and promising breeding work. Even before this cross-breeding work is undertaken, it appears that some of the tetraploids themselves—because they bear larger fruit—may become good commercial varieties.

The U.S.D.A. scientists responsible for this work stress the dangers of being over-optimistic about the colchicine technique. They point out that, while artificial polyploidising often results in thicker branches, broader and thicker leaves, larger flowers and larger and tastier fruit, *some plants show little or no effect and some may even be damaged rather than improved.*

### Synthetic Textile Fibres take Price Lead

The competition between synthetic textile fibres and natural fibres such as cotton has reached an interesting stage. Since the war, reports F.A.O., cotton prices in the U.S.A. have averaged about three times the prewar prices; the peak was reached in 1951, when they stood at 370% of prewar prices. Next year the U.S.A. is to restrict cotton production, and the result of this decision has been sharp rises in the prices of Pakistani and Egyptian cotton.

On the other hand, rayon prices, which had never since the war risen by more than about 30% on 1934–8 levels, were reduced by about 10% in Britain and the United States last year.

Even more considerable reductions have taken place in nylon fibre prices. For the past five years nylon has been selling at about three-quarters of its 1941 price. In January of this year United States prices for nylon staple were reduced by about 12%, and in April British prices for nylon fibres were reduced by an average of 12½%.

Prices of rayon staple were approximately level with cotton prices last year so that these recent increases in cotton prices and decreases in rayon prices give rayon a definite price advantage.

F.A.O. reports a small decline in world wool prices for the first quarter of this year, when they averaged 291% of 1934–8 average prices, in comparison with the first quarter of last year when they were 313% of the 1934–8 average price. There is also a small decline in silk prices for the first quarter of last year, Japanese silk prices now standing at about 306% of prewar prices.

### Scientific Instruments: A 'Booming' British Industry

In 1953 Britain exported scientific instruments to the value of £13 millions and scientific components worth nearly £11 millions. These figures were quoted by Mr. J. Philpot, Director of the Scientific Instrument Manufacturers' Association, at the third annual convention of SIMA at Eastbourne in October, and he pointed out that they represent a tenfold increase over prewar export figures. Yet impressive though they are, they do less than justice to either the growing importance of an industry whose contribution to the modern world cannot be assessed at all adequately in monetary terms, or to the new spirit which has grown up within the industry during the last few years.

As Mr. C. E. T. Cridland (Aldis Brothers), this year's president of SIMA, expressed it, the instrument manufacturers of today "know that science and its commercial application are of equal importance". This, however, is far from being the whole story. The urgent call for scientific instruments of all kinds during the last war, and the ever-increasing call for instruments for measurement and control in the modern post-war factory and for the research laboratory, do not alone account for the 'boom' condition of the industry today. It was apparent at the Eastbourne convention that there had been a complete change in attitude within the industry since the immediate post-war period.

The form of the convention was itself unusual. All the discussions at Eastbourne were informal, the delegates being free to attend any one of the five different panels into which the large range of very interesting topics had been divided. The only formality was the presence of a *rapporteur*, who chaired each session of his panel and then summarised its discussions for the benefit of the final general meeting. The resulting discussions, if sometimes inconclusive, were always stimulating, and plenty of interesting facts emerged.

The rapidly expanding output of the industry was reflected by the resolution brought forward by Panel I (which discussed Productivity and Incentives) calling for each of the 130 member firms of SIMA to take on 50% more apprentices than they at present need owing to the danger of a future shortage of trained instrument makers if the volume of production continues to rise. The same point was stressed by another resolution: this called for an approach to the Ministry of Labour and ask them to introduce a short-term scheme for training young men as instrument makers.

The specialised nature of the industry was reflected in a resolution which called on the Council to ascertain the bulk requirements of steel of the industry as a whole and then ask the steel makers to put on a long run to ensure a sufficient supply of quality steel for the industry as a whole. Apparently a number of firms have found difficulty in obtaining sufficient supplies of the special steels they need. One reason for difficulty is connected with the fact that the batches of special steel which they order are small.

## LETTERS TO THE EDITOR

# "SCIENTISTS IN EXILE"

Dear Sir:

May I express my great appreciation for publishing your article on "Scientists in Exile" (October 1954). It is very encouraging and refreshing to see the silent but very beneficial work of scientists and others, who have found refuge in this country, mentioned by a widely read periodical.

Although not a scientist myself, I have had experiences in this country similar to those mentioned in your article.

As an outstanding personality I remember the late Miss Eleanor Rathbone, M.P., who has been the real angel for refugees herded together in detention camps like Huyton near Liverpool, where the undersigned spent three of the most unhappy months of his life. But for Miss Rathbone's intervention things would have gone hard for him and many others.

Yours truly,
LEO WALTER

*'The Niche',*
*70 London Road*
*Cheltenham, Glos., England.*

Sir:

In what purports to be a review of the recent translation of Lysenko's *Agrobiology*, Prof. S. C. Harland treats us to an extended *argumentum ad hominem*. The perennial chestnuts, now rather decayed and rotten, about "death, persecution and disappearance of scores of devoted workers", political dictation in science, and dogmatism, are propped up by references to conversations held twenty-one years ago.

No suggestion is allowed to peep between the lines that Lysenko and his followers have any serious biological ideas. The label "Lamarckian party line", and "official theories . . . (of) inheritance of acquired characters", coupled with sneers about the titles in the bibliography are all the Professor allows us. The surprising thing is that a book so "devoid of promise" should be given twenty-seven column inches. One is almost tempted to think someone is anxious to prejudice the biological issues.

Yours faithfully,
R. F. PRICE

*5, Clifton Drive,*
*Westcliff-on-Sea,*
*Essex.*

*Lysenko seems to be coming in for a great deal of criticism in his own country, but he does not seem to lack for would-be protectors in Britain. We are only surprised that this was the only letter which followed publication of Prof. Harland's review* (DISCOVERY, October 1954)*; previous experience had led us to expect many more.*—ED.

It is characteristic of the manufacture of scientific instruments in general that it utilises small quantities of high-quality raw materials on which much skilled work must be done.

Some of the most lively discussions took place in Panel 4 ("The Voice of the Scientist") and centred round the relationship between the laboratory and the factory and the manner in which designs for new instruments are developed. Many scientists must find it surprising that frequently the initiation of new designs stems solely from the sales department, and that in a number of firms work on new developments is only authorised through the sales department. There seemed to be general agreement that this is dangerous: if the sales department has overriding control, it was said, then eventually no new instruments would be produced by firms in which this happens. The danger is greater if a firm has no scientist on its board: and apparently this situation does exist in one large firm of scientific instrument manufacturers. In this specialised industry there are some people who attach more importance to what the salesman and the administrator say than to the ideas of scientists. In fact, one encounters considerable vocal support from certain quarters for the argument that this is right and proper because the salesman produces more business than the scientist. But disagreement with this view was expressed by representatives of different firms, both large and small, working in many different fields, during this conference.

There was much discussion about the shape and design of instruments, and some attention was given to the question of whether they should be immensely durable or whether in certain fields cheap instruments with a short service life could be produced with all-round advantage. It seemed that something of a revolution in design has occurred in many fields during the last five years. It is now, for example, generally agreed that it is important that the instrument should have an attractive outer shape, with, in general, less finish inside. Five years ago functional designs were apparently *de rigeur*. This trend was put down to the greater smartness and cleanliness of modern laboratories and the fact that influential visitors are nowadays more frequently shown round—often for propaganda purposes.

Many of the delegates favoured the manufacture of less durable instruments, in some cases designed for definitely limited lives. This approach reflects the fact that many instruments (e.g. in the field of electronics) can become obsolete within five years. It was also said that in a number of fields, heretofore dominated by the concept of British scientific instruments being built for great durability, less durable instruments could be built a great deal cheaper that could do the job just as well. (This consideration applies only to certain kinds of instruments, of course.)

One remarkable fact that emerged from the discussions in this panel was that several firms are sending their instruments out by rail and aeroplane without any packaging whatsoever. One firm, for example, has for some time been sending delicate electronic instruments worth £300 each by rail in this fashion, without any having been damaged. The sight of the instrument apparently impresses its delicate nature on the handler.

At the final session of the convention, the vice-president, Mr. A. W. Smith, presented an encouraging report on the success of the SIMA exhibit at the recent Scientific Instrument Industries Exhibition in Philadelphia—the largest exhibition of its kind ever held. Twenty-three thousand visitors registered at the British stand, and Mr. Smith said he was sure that Britain could get a useful part of the enormous American market, say 1–2%.

While there may be fields in the world of scientific instruments (e.g. that of the expensive high-quality camera) where Britain still has difficulty in gaining an entrance, the present confidence of this industry is reflected in the feeling expressed by many delegates that the Key Duty Industry Scheme is 'featherbedding' British manufacturers and should be removed as soon as other nations—in particular, Germany—gave up their unfair trading practices in this field.

# THE BOOKSHELF

### Exploration of the Moon

Illustrations by R. A. Smith; text by Arthur C. Clarke (*London, Frederick Muller, 1954, 112 pp., 18s.*)

### The Young Traveller in Space

By Arthur C. Clarke (*London, Phoenix House, 1954, 72 pp., 7s. 6d.*)

A little less than a thousand years ago, as the year A.D. 1000 approached, the end of the world was commonly expected. Five centuries later, it was not ideas about the destruction of the earth that exercised men's minds, but a passion for exploration that took possession of them. The cataclysm feared in the Middle Ages did not take place; the new horizons sought and found in the Renaissance proved, on the other hand, a thrilling reality. We may reasonably hope that in this respect history will repeat itself, and interplanetary travel rather than terrestrial obliteration will be the result of today's developments.

It is clear that a vast amount of hard thought, as well as much popular romancing, is being directed towards astronautics. Since youthful imagination is captivated by the subject, Mr. Clarke's book, addressed to *The Young Traveller in Space*, comes as a welcome antidote to a good deal of current 'science fiction'. Here the problems, possibilities and purposes of space travel are set forth plainly and soberly, in an explanatory text aided by excellent illustrations. The matter and style should be fully as interesting, to the normal mechanically-minded boy, as any of the usual thrillers in this field, while the essence is incomparably better. In the last chapter is sound advice "to those who hope that they may one day pioneer on this great new frontier", that they should study science resolutely, take up as a hobby astronomy, model aircraft or radio, and aim eventually at a science or engineering degree. Altogether, this book is a remarkable production, at a remarkably low price.

As its title implies, *Exploration of the Moon* is more limited in scope. Though larger than the other book and embellished with more plates (several of them in colour) it is confined to a detailed discussion of journeys to the Moon, of what will be found, and of what may ultimately be developed there. Mr. Clarke admits, despite his collaborator's highly finished drawings of a hydroponic farm, an overhead transportation system, a nuclear power plant, and even a veritable garden city on the Moon, that "until we know a great deal more, we cannot be certain if the lunar settlement will ever grow into a fully-fledged colony, able to stand on its own feet and perhaps ultimately become independent of the Earth". Undoubtedly it is difficult to see how, even if the Moon could be artificially invested with a breathable atmosphere, that atmosphere could be retained for any length of time by the low gravitational attraction. But the key to all advance is knowledge, and little further knowledge of either the Moon or planets can be gained unless men leave the Earth.

Yet neither a passion for knowledge nor an urge to adventure need be put forward as a dominant motive. Today the dispatch of missiles into outer space offers a challenge to technical and engineering skill, a challenge scarcely more difficult to meet with our present resources than that which the early aviators accepted fifty or sixty years ago. Much preparatory work was done with gliders before the internal-combustion engine arrived to make powered flight practicable; and it may be that effective space vehicles will have to wait until something other than the conventional rocket is available for their propulsion. This, however, does not render nugatory or abortive any of the thought and effort being devoted to the manifold problems now; still less does it suggest that popular interest in the matter should not be stimulated by authoritative and well written books. Financially, the difference in cost between the conquest of the air and the conquest of space appears likely to be of about the same order as the difference between terrestrial and interplanetary distances—although distance is not indeed an operative factor. It follows that adequate development will depend on the provision of public money, to ensure which astronautics will have need of good public relations. Books of this kind represent the first measures towards that end, and therefore may be regarded as serious contributions to an important subject.

E. N. PARKER

### The History of Astronomy

By Giorgio Abetti; translated from the Italian *Storia dell' Astronomia* by Betty Burr Abetti, with Foreword by Sir Harold Spencer Jones (*London, Sidgwick and Jackson, 1954, 345 pp., 34 plates, 2 line drawings, 25s.*)

Of all the sciences, astronomy has the longest history. Moreover, as the first in the field, it had in its beginnings the greatest weight of superstition and prejudice to overcome. Far down the files of time, even in the sixteenth century A.D., Kepler was forced to come to terms with the popular convictions on astrology, excusing himself by the reflexion that Nature had, perhaps, implanted astrological ideas in the human mind as a means of assisting true astronomical research.

Prof. Abetti, who has been director of the Astrophysical Observatory at Arcetri, Florence, since 1923, has written several books on astronomy and the history of science. In this work of some 350 pages he has set himself, successfully, a most difficult task of compression, and by dividing his story into three parts, dealing respectively with ancient and medieval astronomy, the Copernican revolution, and modern developments, has produced a continuous narrative of progress. True, the very latest advances are omitted, for there is no mention of the radio telescope, but clearly a book of this range must have been planned some time ago, and it is at least embellished with many admirable photographs taken with the 200-inch reflector at Mount Palomar.

The translation, although generally smooth and readable, is not faultless. *Ursa Major*, for example, is not very happily rendered into English as the Big Bear, although it appears in the index with the more conventional adjective 'Great'. Nor should Eddington's *New Pathways in Science* be given the inaccurate and misleading title "New Ways of Science", particularly when Eddington's work is quoted by the author with such appreciation. Indeed Prof. Abetti is as much impressed as Eddington was by the international character of astronomy today. He prints in full the preface to Eddington's lectures on the expanding universe delivered at Cambridge, Mass., in 1932, and concludes his book with a good historical description of the world's leading observatories and of the International Astronomical Union. Between his chapters on "Nineteenth-Century Astronomy" and "Twentieth-Century Concepts" is placed fittingly a chapter on "Some Modern Observatories"—fittingly, because it is the work at these, carried out with magnificent equipment, that has brought the present outlook into being.

Yet the history of astronomy shows plainly enough that elaborate and costly instruments, however essential they may be after a certain point has been reached, are not everything. The painstaking observations of Tycho Brahé, made without optical aid but with massive quadrants for exact measurement, and the almost incredible mathematical labours of Kepler, are among the epics of science, and are highlights in the achievements of the human mind.

E. N. PARKER

### Heat Transmission

By W. H. McAdams (*New York and London, McGraw-Hill Book Co., 3rd Edition, 1954, 532 pp., 61s.*)

This is the third edition of the standard work on heat transfer. There are other books which have a different, and valuable, approach, but if one was allowed only a single book on this subject this is the book one should choose. It incorporates a great amount of new material arising from the development of nuclear reactors and jet engines, and only recently declassified. The sort of new problems which have had to be tackled are now widely known, such as the need

to refrigerate supersonic aircraft or the transfer of heat energy from nuclear fission at high rates per unit area to molten metals. Besides these, new industrial techniques such as the fluidised systems of catalytic crackers have required treatment. The value of this edition, as of the earlier ones, lies to a great extent in the illustrative examples which are fully worked out.

F.E.W.

**Radiation Biology, Vol. I: High Energy Radiation, Parts I and II**

Edited by A. Hollaender (*New York and London, McGraw-Hill, 1954, 1265 pp., 140s. the set; the two parts cannot be bought separately.*)

It is eighteen years since B. M. Duggar published in two volumes his *Biological Effects of Radiation*. During those years many important discoveries have been made; the spectrum of radiations has been extended, the measurement of radiations has greatly improved, and with the discovery of nuclear fission new sources and types of charged particles have become available for investigation. Because of the hazards which hinder, and may even prevent, the fullest application of nuclear energy, the study of the biological effects of radiation has been particularly intensified in recent years.

This is the background against which one should consider the publication of the first volume of *Radiation Biology*, which is edited by A. Hollaender, the director of the Biology Division of Oak Ridge National Laboratory, U.S. Atomic Energy Commission. This volume opens a new series of books which has grown out of a plan to revise Duggar's outdated opus, a scheme that had to be abandoned in the face of such a great amount of new data requiring presentation. The new series of volumes is intended to replace Duggar's monograph. The editor is assisted in his task by a panel of experts.

The two books under review constitute the first volume of *Radiation Biology*, and their bulky contents of over 1200 pages deal with "High Energy Radiations". Two more volumes are to be published, one on "Ultraviolet Radiations" and the other on the effects of "Visible Light".

The eighteen chapters of the first volume cover a very wide range of topics. There is much up-to-date information on the physical fundamentals of radiation and radiation chemistry; in these aspects the chapters by U. Fano, W. M. Dale and E. S. G. Barron are excellent. The importance of the linear spacing of the ions and excited molecules in biological reactions is discussed in Chapter 6 by R. E. Zirkle in terms of energy transfer. The extreme complexity of the mechanism by which the biological effects are induced is shown by the fact that, when the spacing of ionisation in the track of the particle increases, the relative effectiveness of the various radiations may remain unchanged or may increase or decrease, depending on the nature of the irradiated object and upon the effect studied!

The first six chapters deal with the physico-chemical basis of radiation and can be considered to be an introduction to the interpretation of the diverse biological effects which are described in the following chapters.

The nature of the genetical effects and the manner in which they are produced by radiation is discussed in Chapters 7 and 8, both written by H. J. Muller. According to him, "the gravity of the genetic effects is of a different order of magnitude from that of all the other biological effects of radiation in that the genetic effects are essentially irreparable", and the statement may help to explain why this topic occupies one-quarter of *Radiation Biology*. Muller not only discusses the effects of radiation, he also uses the data to define the properties, nature, structure and behaviour of the genetic material (genes and chromosomes). Muller maintains the view that genes are discrete units in the chromosomes "sharply" demarcated from one another, rather than "form one chemical continuum". The reader is informed that about 60 roentgens doubles the "spontaneous" mutation rate in *Drosophila*, but in man less than this dose can seriously affect the genetic make-up. The accumulation, expression and elimination of mutations in a population is described, and the manner of incidence of radiation damage in subsequent generations is discussed. Muller gives a serious warning about the genetical hazards to which the human population may be subjected if it is exposec by radiation. In Chapter 8 the reader will find information about chemical mutagenesis, the influence of water and oxygen in radiation reaction, protective substances, cosmic radiation, nuclear transmutation, carcinogenesis, etc.

The extensive part which is devoted to the genetical effects of radiation unfortunately casts its shadow over the two following chapters by B. P. Kaufmann and N. H. Giles which deal with chromosome aberrations induced in animal cells and in *Tradescantia*. Many aspects of these subjects have already been presented by Muller, and the reader will find several instances in which the latter authors disagree with him regarding the interpretation of certain radiation effects. The genetic effects induced in mammals is presented by W. L. Russel, and much of his data is derived from his own excellent work on mice. Russel points out that the mutation rate per roentgen per gene is higher in mice than in *Drosophila*, on which our present-day estimates of human hazards are based.

The radiation effects on the pre-natal development of experimental animals as well as that of man are described by L. B. Russel. We learn from her excellent chapter that doses as low as 25 roentgens can be effective in producing developmental changes if the exposure of radiation has taken place during the first 6 weeks of gestation. The pathological physiology and histology of radiation injury is covered in Chapters 14–17 by different experts. This section is good and informative, but unfortunately it involves much duplication. The last chapter deals with the carcinogenic effects of radiation and includes information on the biological hazards connected with radioactive isotopes.

Each chapter in the book has an extensive list of references, and there is a good author and subject index at the end of the volume.

The volume will serve as a rich source of information and, in spite of the fact that the rapid progress in Radio-biology will no doubt soon make many of the interpretations given out of date, it will be indispensable to all who are interested in the effects of radiation. In the present volume efforts have been made to include the latest information in footnotes, which should help the reader to make corrections to passages in the main text which became out of date in some respects while the book was in process of preparation. It may be hoped that the fault of repetition and overlapping so widespread in the present volume will be remedied in future editions.

P. C. KOLLER

**The Hydrogen Bomb**

By James Shepley & Clay Blair, Jr. (*New York, David McKay Co., 1954, 244 pp., 3 dollars*)

This volume, written by two of *Time* news magazine's Washington bureau, must have been produced at a cracking pace in order to catch a market for a book about the personalities involved in the hydrogen-bomb project. Many of these men gave evidence in the Oppenheimer case, and much of the incidental detail in the book obviously comes from the official verbatim transcript of the Oppenheimer inquiry, but it includes a good deal of additional material. There is no doubt about the authenticity of some incidents related in it, but in order to string all the various incidents together into a snappy narrative the authors must have indulged in a certain amount of guesswork, and consequently one is hard put to decide whether some of the stories they tell are genuine or merely plausible.

They certainly achieve the semblance of plausibility throughout the book, but the authors' portraiture of the leading personalities lacks depth—the characters in this drama are depicted solely in terms of black and white, with scarcely a grey tone to add realism to the pen pictures.

The book opens very effectively with a chapter describing how in late August 1949 a lone U.S. Air Force bomber, which had been sent out on a harmless mission to expose a set of photographic plates to bombardment with cosmic rays, came back unexpectedly with the first American record of the explosion of 'Joe One'—the first Russian atomic bomb. Confirmatory evidence was soon obtained, by both the U.S.A. and Britain. At the time the United States was cutting back its expenditure on arms, and there was reluctance in official quarters—notably in the Defence Department—to accept the fact that the Russians had broken the U.S. monopoly of atomic weapons. The Russian bomb explosion had come as a grim surprise; even to the U.S. Air Force which,

according to this book, had estimated that the Russians would have an atomic bomb by 1952—an estimate which was generally regarded as pessimistic prior to the explosion of 'Joe One'.

Most of the work on the H-bomb was done after that explosion; indeed it was the explosion which prompted the H-bomb project proper. Men like Lewis Strauss (now chairman of the Atomic Energy Commission) could press home the telling argument that the U.S.A. must go forward with work on fusion bombs since the Russians were bound to do so after their success with fission bombs.

The scientists of Los Alamos had given some thought to the possibility of making a fusion bomb early on in the war. In 1946 there was a conference at Los Alamos to discuss this idea (at which, according to the authors, Klaus Fuchs was present). No action seems to have resulted from that conference, and the authors claim that Oppenheimer and his associates used their influence to prevent any action being taken in 1946.

As the book gets into its stride, Dr. Teller and Lewis Strauss become the heroes of the story, and Oppenheimer is pictured as the nigger in the A.E.C. pile. Undoubtedly Teller and Strauss deserve praise for the pertinacity with which they fought down the solid opposition that faced them in their campaign to get something done about the H-bomb; apart from Prof. E. O. Lawrence and Senator McMahon they were practically without any influential allies; the decision of President Truman (announced on January 31, 1950) to go ahead with the H-bomb project came as a big surprise, to Teller and Lawrence at least, for at that time the opposition to the project far outnumbered the men who favoured it, and that opposition showed no sign of weakening.

The authors are quite possibly correct in their belief that the Russians would have won the hydrogen-bomb race had it not been for the persistence of Strauss and Teller. The next two chapters in the book, however, have probably done a disservice to Teller in that they give so much credit for the technical achievements in the H-bomb project to Teller and so little to the scientists of Los Alamos. (The director of Los Alamos, Dr. Norris E. Bradbury, has certainly taken offence at the slur the authors cast on his laboratory, though any impartial observer is likely to sense that Dr. Bradbury, in his evidence at the Oppenheimer inquiry, was claiming almost every bit of credit for the Los Alamos team and doing so at the expense of Dr. Teller. *The Hydrogen Bomb* did in fact provoke Dr. Bradbury into issuing a statement, which set out to deny that there was any reluctance among Los Alamos scientists to design a hydrogen bomb, and ended by a categorical statement that "thermonuclear work never stopped" at Los Alamos, which, if taken at its face value, is hard to reconcile with some of the statements made during the Oppenheimer inquiry.)

The book has a good deal to say about what it calls "the anti-H-bomb lobby" which campaigned publicly against the H-bomb after the President's announcement of January 1950. This section of the book must have aroused much ire among many leading American scientists, who are named as partisans in what the authors present as a well-organised campaign—but which was quite possibly nothing more than a controversy that was almost completely one-sided because the scientists knew the facts and could state a case, whereas most other people did not know enough to be able to discuss the pros and cons of the H-bomb project effectively.

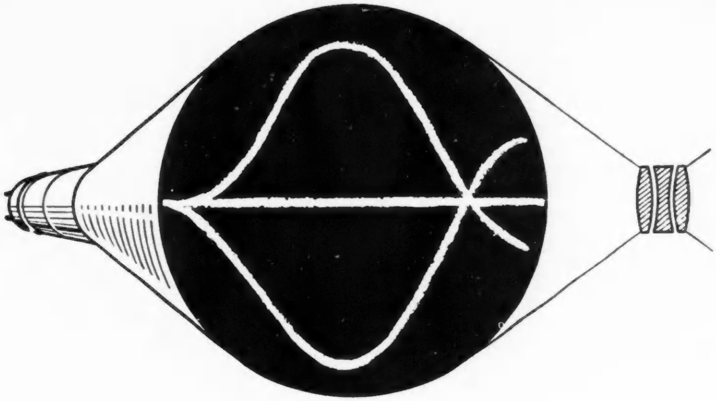
The book has a chapter on the first thermonuclear test; and another on "Operation Greenhouse", which proved beyond doubt that fusion bombs were feasible. In both chapters everything appears to revolve around Teller, who by now had gained influential support from some military men but was apparently frustrated by an active scientific opposition. (Here the authors make one very serious allegation against the director of Los Alamos, who is figured throughout the book as a puppet whose strings are manipulated by Oppenheimer.)

The next chapter deals with the setting up of the Livermore Laboratory—a new atomic weapons laboratory miles away from Los Alamos where Teller could work without frustration. At this distance from the U.S.A. it is not possible to assess the relative importance of the work that was done on the H-bomb in these two laboratories. In view of the size of the Los Alamos team (Dr. Bradbury has recently stated that there are 3000 in his laboratory), the sum total of its contributions to the H-bomb achievement must have far exceeded in magnitude the contributions of Livermore. The summing-up of this matter in the book seems to be altogether too glib: "Events were to prove that initially the greatest use of Livermore would be to energise Los Alamos, as Teller had long predicted. Once it was actually faced with a competitive situation, the Los Alamos Laboratory threw its full energies and very great talents into the thermonuclear programme. In the end the more mature staff and the more experienced scientists at Los Alamos significantly outpaced the new laboratory at Livermore in providing the hardware that became the hydrogen bomb." The time-scale of H-bomb seems to be all wrong in this passage, for it was quite late in the day when the Livermore Laboratory came into effective operation. It should have been possible for the authors to give all due praise to Teller without simultaneously minimising the credit due to the Los Alamos staff; they may have no time for the director or ex-director of Los Alamos, but their attitude towards the whole laboratory seems to suggest that they are prepared to visit the sins, real or imaginary, of the head of a laboratory on every man jack who works in it.

The story of H-bomb development ends with a chapter on "Operation Ivy" (in which the island of Elugelab was wiped out, leaving a crater over a mile wide and 175 feet deep in the ocean bed); and another on the post-Ivy tests, including the one which showered the hapless Japanese fishermen of the Fukuryu Maru with radioactive ash.

The last six chapters are largely concerned with the faults of scientists who meddle with political and military matters. The authors' main target is Oppenheimer, and to him they show no mercy; they give him a chapter all to himself and they call it "Less than Candid"—the choice of this phrase from the Gray Board's report seems a singularly nasty trick to play on a man who has paid in full for all the mistakes and errors of judgment he may have made.

Science, political and military affairs are now inextricably entangled in a way which many people regret in the same way that the Luddites regretted the invention of machines; recent experience indicates that so long as nations have navies, armies and air forces they never will be disentangled. Oppenheimer is not to be condemned because he stuck his nose into political and military affairs; others have done it before, and others will have to do it again. The authors of *The Hydrogen Bomb* do not seem to realise that in this world in which scientific power is one source of political power some scientists are bound to be given responsibilities every bit as great as those of political and administrative chiefs. The men who fill such posts of special responsibility are not chosen solely for their scientific abilities; they cannot be judged solely by the standards one applies to the question, Is this man a first-class scientist or not? One suspects that the real tragedy of Oppenheimer is that he acted as a politician would, but expected to be judged by purely scientific criteria. In the political world, one mistake that embarrasses a man's colleagues can end a promising career. Something of that sort happened to Oppenheimer. Over the H-bomb controversy Oppenheimer seems to have made some wrong judgments, whereas Teller backed the right horse. Oppenheimer's downfall from his exalted position in the world where political, administrative, military and scientific affairs now meet was swift and complete. Those scientific men with experience in that world and who thought Oppenheimer had made some serious mistakes tempered their judgment on him with mercy—only the most case-hardened could escape thinking of the saying, "There but for the grace of God go I." The authors of this book are quite unmerciful in their judgment; they judge everything according to the pragmatic standards that govern the world of professional politicians. Most scientists will not find this book pleasant reading, but is a book that they ought to read nevertheless, for it is important that scientists whose work revolutionises such things as military technique, and therefore affects the whole international balance of power, should take into account the opinions of men outside the world of science. The public attitude towards scientists and science is much influenced by books such as this one; that may seem regrettable, but it cannot be ignored.



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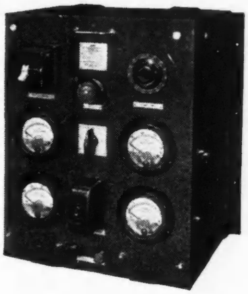

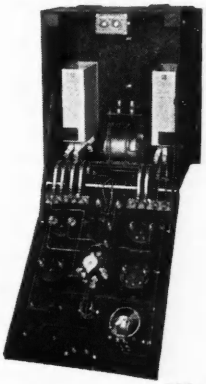

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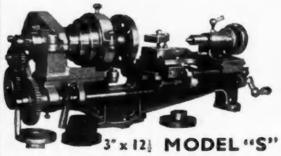

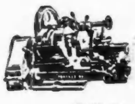

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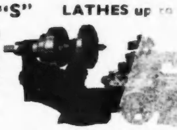

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